the petersen automotive troubleshooting & repair manual

by the staff of
Petersen Publishing Company

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Basic Automotive Troubleshooting for All Cars, and Basic Automotive Tools and How to Use Them.

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introduction

This is a new and different kind of book—in fact, it's three books in one. It's a repair manual, a trouble-shooting guide, and a tool book—combined between two covers to make it simpler for you to find automotive problems and to fix them easily and quickly, using the proper tools and techniques.

The book's basic, general sections describe the various systems and components of your car—how they're designed, what makes them work, what might go wrong, and how to perform do-it-yourself repairs. (It also tells you when to call in professional help, where special expertise and tools may be required.) Included are numerous, fully illustrated "how-to" features that clearly picture the sequential steps to follow in repairing or replacing faulty elements.

The troubleshooting portions of the book are contained within the respective subject chapters, so that handy cross-reference between description and diagnosis is possible. The clearly understandable text and the detailed line drawings make locating and verifying the problem a simple task. Like the tool section described below, the troubleshooting segments are presented in large, easy-to-read type, to facilitate quick-glance reference when the book is spread out on your car's fender or on your workbench, and your eye must repeatedly jump back and forth from the part being analyzed to the instructions in the text.

The book's third "bonus" section covers the basic automotive tools required to perform the usual garage or driveway mechanical chores. Here again, the simplified approach to describing the functional differences between the various tools, and illustrating the correct way to use them, will enable you to save time, money, skinned knuckles and tool-damaged car parts. No matter what you may understand about your car's problems and how to fix them, there's not too much you can do unless you have the necessary tools and know how to use them properly.

This volume will serve you in many ways. It will enlighten you about many of your car's seemingly complex systems and components, helping to build the do-it-yourself self-confidence that can come only with knowledge. It will show you how to make your tools do the work for you, as they should. In an emergency, it will provide you with invaluable find-it-and-fix-it tips distilled from the wisdom of professional mechanics.

One thing else. Don't tuck this book away in your garage, or lose it on your library shelf, or hide it in the car trunk. Between the times you use it to work on your car, it can bring many hours of informative reading for you, your spouse, your children—anyone who wants to or needs to know more about the family automobile . . . and how to keep it operating better, longer.

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Prepared under the direction of Erwin M. Rosen

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The Right Tools for the Job

A mechanic without tools is like a wheel without a tire. A wheel, thankfully, is satisfied with only one tire, but a mechanic never feels that he has enough tools. Part of being a mechanic is fascination with the sight of a full toolbox, a love of all the different sockets and extensions, handles and ratchets, and even some gadgets that haven't been used for so long that it's difficult to remember what car they were designed for, or even how they work.

The best advice we can give you about buying tools is to investigate before you buy even so much as a simple pair of pliers. Get as many catalogs as possible from the tool companies, and go to the retail stores so you can see and handle the merchandise. In many cases we have seen mechanics get started with a basic set of hand tools, only to discover later that another brand was much more appealing to them. The result was they switched to the other brand, and the money spent for the original basic set was wasted. It makes no difference whether you buy Snap-On, Proto, Sears' Craftsman, Ward's Power-Kraft, Mac, or any other brand. The important thing is to know about them all before you make that necessary purchase of your basic set.

In some brands you can save a lot of money by getting a set instead of individual tools. But beware of enormous sets that include everything from thread gauges to wheel pullers, with maybe a backscratcher thrown in. After all, you may find that you like one maker's socket sets, but not his pliers. And you may go to a third manufacturer for your screwdrivers, simply because you like the way they are made. Some of the small toolmakers do an excellent job on special-purpose tools for brakes, or engines, or electrical work. In many cases they are the only source for a special tool that is just what you need.

Major brand tools are not discounted to anybody. The backyard mechanic pays the same price as the guy who works on the line at a big car dealer. Some big-city hardware stores may have a line of hand tools that they discount, but such places are hard to find, and the amount you get off is only about 10%.

The best place to find different makes of tools is at an automotive parts store. The counterman is usually out of catalogs, but you can get the address of the factory from him and write for one. Some tools, including the best hand tools available, are not sold in retail stores, but only by wagon peddlers. The peddlers usually leave their calling cards all over town at the various independent garages and car dealers. Ask your local mechanic for the phone numbers of the various wagon peddlers that call on him.

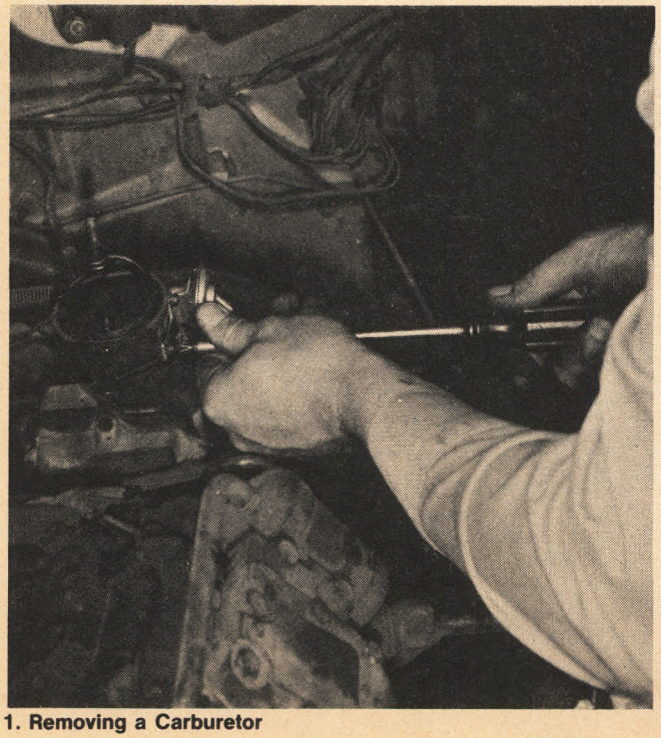
Don't ignore the mail order houses, either. Sears and Ward's have excellent tools. Incidentally, their catalog price is usually less than you would have to pay in the retail store.

For the purpose of properly selecting and using the basic hand tools for fasteners, some knowledge of those fasteners—particularly the nuts and bolts—is very important to any type of repair work. It is not only a question of the proper wrench for the nut or bolt but of the proper bolt size and how tight it should be twisted.

UNDERSTANDING FASTENERS

Fasteners vary not only in a wide range of sizes and thread count, but also in the type of material from which they are made. Increased strength for a particular assembly is not always achieved by installing a larger bolt, but very often by the specified use of a stronger bolt material. Critically stressed parts of an automobile such as the suspension, steering and structural assembly generally use nuts and bolts of a higher tensile strength than those used just to hold accessories. Sheetmetal screws, for example, may look like some of the available wood screws, but they are treated for hardness and will withstand threading into a punched hole under stresses that just twist off wood screws.

Bolt and cap screws are easily identified by distinctive markings embossed on the heads which denote the type of ma-



1. Removing a Carburetor

2. Toolboxes

terial and, therefore, the tensile strength range for proper torquing. The word "torque" will continue to crop up in specifications relating to everything from spark plugs to cylinder head nuts, and is a very important function of the strength of bolts and the pieces held together by them.

Before proceeding further with torque, it is best to clarify the method of identifying fasteners by strength rating. Bolt heads are embossed with a series of lines radiating outward. Plain-headed bolts without markings are the most common to the hardware store purchaser. They are graded as 1 or 2 by the SAE (Society of Automotive Engineers), and are adequate for most accessory fastening jobs requiring only low-carbon steel strength.

Generally specified for automotive use is the SAE grade 5, noted by three embossed lines on the head and with nearly double the tensile strength of the common low-carbon, plain-headed bolt. Slightly higher in strength are the grades 6 and 7 noted by 4- and 5-line markings respectively, and topping the commercial grades is the 6-liner for use in severe stress points and on heavy-duty trucks and construction equipment.

Carriage and stove bolts are not recommended as replacement for even the lowest SAE grade of bolts, although they have their place in the fabrication of many common items. Machine screws with special heads such as flat, fillister, round, and pan designations are not usually marked except in aircraft grades.

Allen-head cap screws are unmarked, but they are usually grade 8 or better. Unfortunately, frequent use tends to round off the corners of the wrench or to strip out the head. If working space permits, you should change over to hex-headed cap screws. The strongest cap screws are made for aircraft, but they are also the most expensive, unless you can find them in a surplus store.

Thread patterns, noted by the bolt size and a single number which means the number of threads per inch (4-40, 10-32, ¼-20, etc.) for machine screws, nuts and bolts, are important especially when the fastener is used in a threaded hole. All

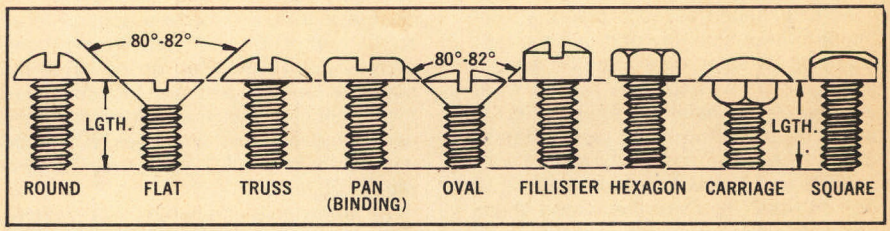
1. Fifty bucks worth of hand tools should cover what the backyard mechanic needs to effect 90% of the repairs that would shape up the old clunker. A set of wrenches, a couple hammers, screwdrivers, pliers, bench tools and the "Basic Auto Repair Manual" can save the do-it-yourself hundreds of dollars in bills. A screwdriver is all that's needed to replace this choke vacuum actuator.

2. Multi-piece toolboxes usually find a home among the professionals. But many serious amateurs also tie up hundreds, even thousands of dollars in sets like these shown. Most packages include ¼, ⅜ and ½-in. drives, a full complement of ratchets, extensions, breaker bars, torque wrenches, sockets, speed handles, end wrenches, hammers, pliers, punches, drills and mikes.

3. Cap screws or bolts are available in varying head designs, all tailored to do a specific job. Some must be tightened by screwdrivers, others by various types of wrenches.

4. We call them bolts, nuts, washers, etc., but the trade refers to them as fasteners. Obviously they come in varying grades depending upon their use and/or need. High-stress areas—like the clutch or crank—require employment of a strong type of cap screw material. Low-stress areas—manifolds or carburetors—can use a lesser strength material.

5. Cap screws too have their design terminologies and characteristics. The better a mechanic understands the whys and wherefores of fasteners, the easier it will be for him to select the right grade and the right torque.

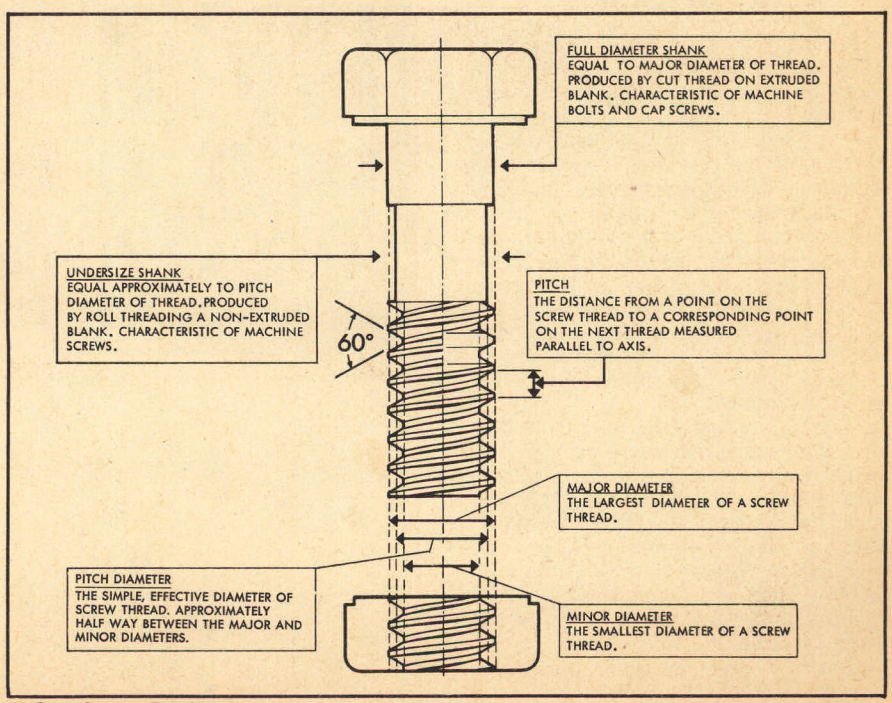


3. Cap Screw Head Designs

GRADE MARKINGS					
DEFINITION	No lines unmarked Indeterminate quality SAE Grades 0-1-2	3 Lines—common commercial quality Automotive & AN Bolts SAE Grade 5	4 Lines—Medium commercial quality Automotive & AN Bolts SAE Grade 6	5 Lines—rarely used SAE Grade 7	6 Lines—Best commercial quality N.A.S. & Aircraft Screws SAE Grade 8
MATERIAL	Low Carbon Steel	Med. Carbon Steel Tempered	Med. Carbon Steel Quenched & tempered	Med. Carbon Alloy Steel	Med. Carbon Alloy Steel Quenched & tempered
TENSILE STRENGTH	65,000 p.s.i.	120,000 p.s.i.	140,000 p.s.i.	140,000 p.s.i.	150,000 p.s.i.

GRADE MARKINGS						
DEFINITION	Supertanium	A-354-BD. A490	Socket Head Cap Screw Also N.A.S. Aircraft Std.	N.A.S. 144 Aircraft Std. MS 20000 Mil. Std.	N.A.S. 624 National Aircraft Standard Steel	Aircraft No Number Assigned Steel
MATERIAL	Special Alloy Steel Quenched & tempered	Med. Carbon Alloy Quenched & tempered	High Carbon Alloy Quenched & tempered	High Carbon Alloy Quenched & tempered	High Carbon Alloy Quenched & tempered	High Carbon Alloy Quenched & tempered
TENSILE STRENGTH	160,000 p.s.i. minimum	150,000 p.s.i.	160,000 p.s.i.	160,000 p.s.i.	180,000 p.s.i.	220,000 p.s.i.

4. Fastener Grade Marking Chart



5. Cap Screw Design

Right Tools for the Job

of the commonly used machine screws or bolts are made in two thread series, coarse and fine, and it is important that even though the bolt diameter is correct for the hole, the threads match those in the hole.

Internal threads and those on the bolt should always be clean and free of damaged or flattened sections before you attempt to assemble any part using threaded holes. Greater care must be taken if aluminum is involved. This applies to everything from installing spark plugs to assembling aluminum transmission cases. Even the poorest grade of steel bolt will cut its own thread in aluminum or soft steel if it has the wrong thread per inch pattern or if it is started into the hole improperly.

A good practice for any assembly is to first try all of the bolts *by finger effort only* into the threaded holes to check for both length and thread. Any doubt about the force required to thread the fasteners by finger pressure should be followed by an examination of both male and female thread condition. Slightly damaged threads on a bolt can be dressed up by filing with a slim 3-cornered file or a thread file, a handy tool in any mechanic's kit. These have eight different thread pattern filing sides and are reasonably priced, but worth a fortune when really needed.

Dressing up inside threads, if only slightly damaged, is best done by running the proper tap into the hole. While not absolutely necessary as part of the basic tool kit, a few taps in the most common sizes will come in handy especially when you are working on older cars that may have been badly repaired by the previous owner. Before getting into the total repair of damaged inside threads, it is best to consider the tools in common use for standard nuts and bolts.

END WRENCHES

Anyone looking at a set of standard open-end, box-end or combination wrenches will immediately notice how the total length increases with the size of the opening. This in itself is a sort of primitive built-in protection against overtightening as it limits the leverage and consequently the foot-pounds of torque that one can apply. It does not consider the strength of the individual, which can often mean a twisted-off bolt. Wrench sizes for American standard nuts and bolts are given in fractions of an inch and note the distance measured across the parallel flat sides of hexagon (6-sided) nuts and bolts.

Metric nuts and bolts are measured across the same dimension with the corresponding wrench size given in millimeters. British cars used to use the British standard system which is measured at the bolt shank diameter. A wrench marked 1/4 W (Whitworth) is made to fit a 1/4-in. bolt, even though the head dimension is 7/16-in. British cars now use American sizes.

Open-end wrenches exert their force against a pair of the parallel sides, and it is important that the proper size wrench be used. Naturally, one too small will not even fit, but too large an open end will result in insufficient contact area to exert the proper force. It will burr the corners enough to impair the use of a wrench of the proper size, and make it impossible to fit a box-end or socket on the bolt head or nut.

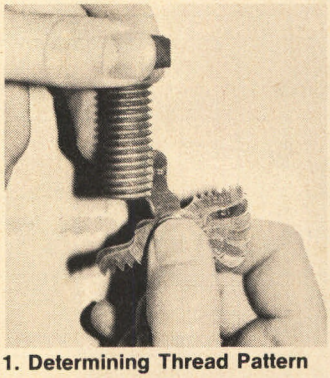
Box-end wrenches and sockets apply their force on a small area on either side of the bolt or nut corners, but unlike the open-end tool, the force is applied to all six corners at once. These are the common 12-point type used on box-end and socket wrenches and are recommended for all general use. A set of combination open- and box-end wrenches is a good investment and will handle most general repair projects.

The adjustable-end wrench or "Crescent" is made by most tool manufacturers, including Crescent Tool Co., and is a very handy tool for the occasional mechanic for those jobs beyond the capacity of the average wrench set. A 10- or 12-in. adjustable will handle sizes slightly over 1 in., saving the need for an investment in an open/box-end set of the larger sizes. Adjustables also come in small editions with a maximum opening of ½-in., and there are click-stop models that hold the jaws firmly at preset positions. One of these, along with a good screwdriver and a pair of pliers, is nice to carry in the glove compartment just for on-the-road emergencies.

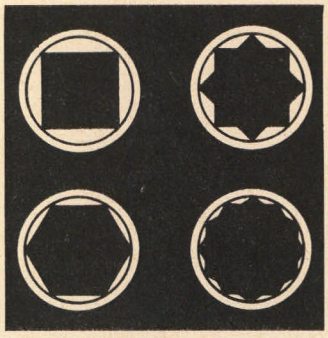
SOCKET WRENCHES

Socket wrenches are desirable for their adaptability to a variety of hard-to-reach places. Their speed when used with ratchet handles is a great aid in any mechanical work and no professional mechanic is without a full set of sizes, lengths, and adapters. Screwdriver and Allen screw bits increase the versatility of a socket/handle set and are ideally suited to applying great force in cramped spaces with the right-angle action of such a combination. In addition to these special ends, sockets for nuts and bolts are available in 4, 6, 8 and 12 points. The 4- and 8-point sockets are for square-headed fasteners, while the 6-pointers are mainly for power impact tool use on hex-nuts and bolts.

A common term used in connection with sockets, and the handles for them, is "drive." The connection between socket wrench and handle is by a square projection on the handle fitting into a similar hole in the drive end of the socket. The size of this connection is ¼-in., ⅜-in., etc., up to 1 in. in the standard and most commonly used tools. The size

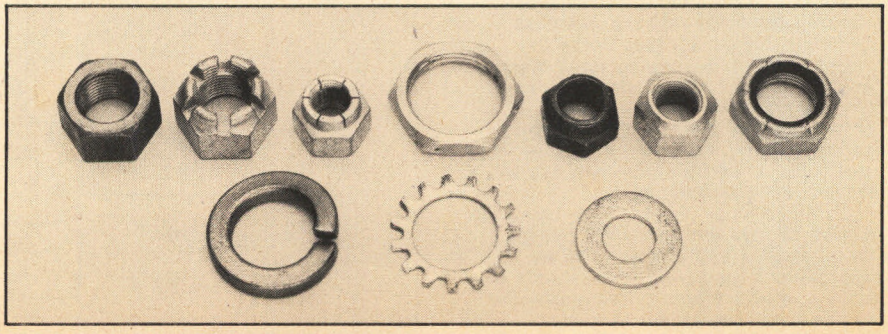


1. Determining Thread Pattern



2. Socket Configurations

3. Types of End Wrenches



4. Types of Nuts and Washers

1. Thread size and pattern is either coarse or fine and is best confirmed by the use of this simple thread gauge. In any automotive application, one must use the correct pattern and cap screw diameter. If not, you'll strip the threads or break the bolts.

2. Sockets encompass 4, 6, 8 and 12-point configurations. The 4- and 8-pointers are used when fasteners with square heads are encountered. The 6-point types must be employed with impact wrenches or in high torque situations so as not to round off the edge of the bolt head. However, most general repair work features the use of 12-point sockets.

3. The simple end wrench can be purchased as either a box-end (left), open-end (right) or a combination of the two (middle). Box-ends come in handy as a breaker or final tightener. The speedier open ends are better for hard-to-get-at places.

4. What applies to cap screws also applies to nuts and washers. They come in an infinite variety of shapes, sizes and grades. In top row (from left) is a standard, castellated, SPS Flex-lok, jamb, Cone-lock, L&S Stover lock and a nylon insert locknut. Below (from left) is a lock, external tooth and flat washer. To prevent galling, flat washers must be made of the same material as the nut, and the nut must be identical in grade to that of the cap screw.

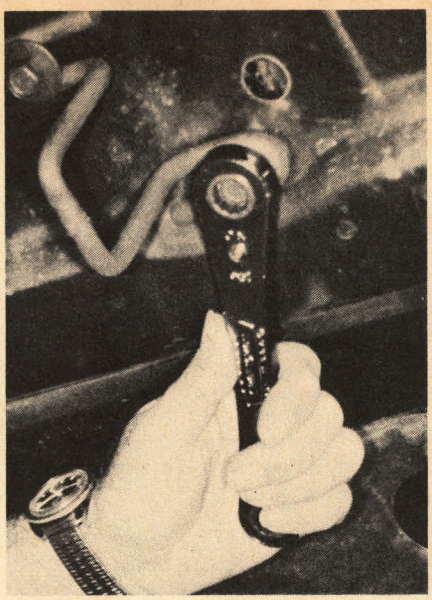
5. A ratchet box-end wrench is handy in tight places as well as for general use. It speeds up the loosening/tightening process and seldom slips off the bolt head, saving you a lot of knuckle skin in the long run.

6. Every backyard Bignotti should have a couple of crescent wrenches—especially if he owns one of the new, foreign-built subcompacts with their metric bolts and nuts. Crescents will also save you the cost of buying large sockets and/or end wrenches.

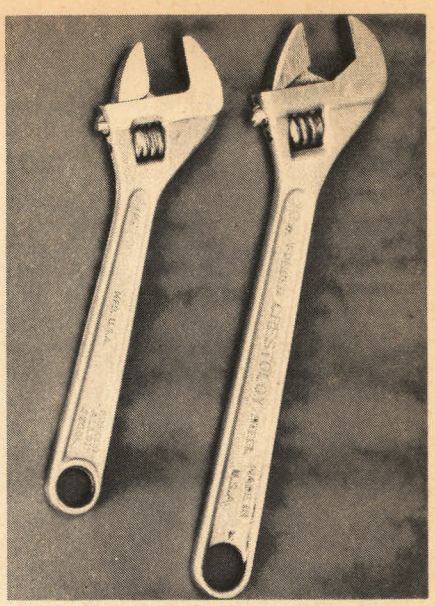
7. Most socket sets (breaker bars, U-drives, extensions, ratchets, etc.) come in ¼, ⅜, and ½-in. drives. Small (¼-in.) drives are useful for electrical and body fastener work, the ⅜-in. drive comes in handy when working on the outside of the engine, and the larger ½-in. drive is usually employed in general engine overhaul work or suspension repairs.

8. Common torque-indicating wrenches include such units as (left to right), Continental American's round beam, which has a 100 ft.-lbs. torque capacity; Milbar's micrometer adjustable, which clicks when dialed-in reading is reached; S-K Tool's round beam model indicates from 0-150 ft.-lbs.; Milbar's dial unit, using a sensory dial indicator, calculates up to 600 in.-lbs. All are precision made.

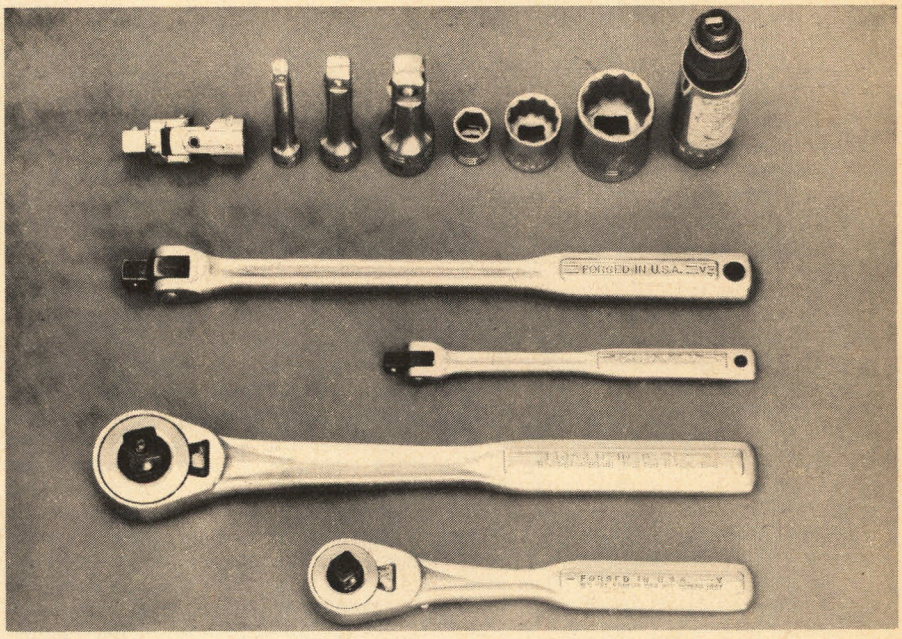
9. This 8-in-1 wrench is a tool box space-saver. Swivel ball heads let you adjust angle for best leverage as well as for getting in and out of some of those really tight places.



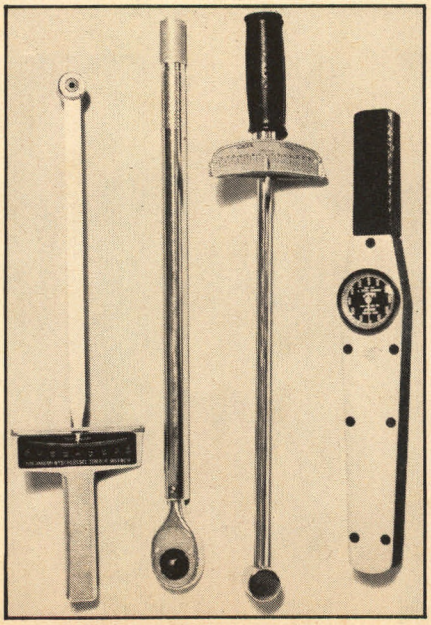
5. Ratchet Type Box Wrench



6. Crescent Wrenches



7. Socket Set



8. Torque Wrenches

9. Multiple Box Wrench

Right Tools for the Job

of the drive is in proportion to the socket size, giving the strength needed for handle length and bolt size. Handles for socket drives come in a variety of models as to length, ratchet, swivel, screwdriver, speed and flexibility, with universal and step-down adapters for using sockets of a different drive size than the handle. There are also open and "crowfoot" wrenches, Allen or Phillips drive bits and ratchet spinner attachments for socket sets, making them a most versatile tool.

A good set of sockets is a must for precision work; it will save a lot of busted knuckles and damaged nut and bolt heads. Just about every part on an automobile held together by bolting has a specific degree of tightness or torque specifications for it. This torque setting is specified for both the tensile strength of the fastener and the required degree of fit or tension between the mating parts.

TORQUE AND TORQUE WRENCHES

Every type and grade of metal has a limit to which it can be safely stretched or stressed. There is an engineering phrase that says, "An over-torqued bolt is already half broken"—which is a good indication of just what degree of stretch fasteners of this type can take. Designers consider many things in selecting the proper size and material for a fastener. As engines, transmissions and suspension components become more complex, their efficiency becomes more and more dependent on just how the various parts are held together. Applying just the right amount of torque or stretch to the fasteners imparts the correct amount of pressure needed to hold the parts together without distortion.

In the case of aluminum and other soft metals, their ultimate strength governs the amount of torque rather than that of the steel bolt. Allowance for heat expansion or soft joints sealed by gaskets also must be considered when applying torque, as too much pressure could damage or distort the two mating parts.

Tension is not to be confused with torque. Tension is the stretching force along the length of the bolt, or its degree of stretch. Torque is the force required on the bolt or nut to produce the desired degree of stretch in the fastener; it is measured in foot-pounds (ft.-lbs.) or inch-pounds (in.-lbs.). Torque is measured on the basis of a fundamental law of physics regarding leverage: Force times distance equals twist force or torque around a pivot point. If 1 lb. of force is exerted around the bolt or nut center at 1 ft. from that center, the torque is 1 ft.-lb. If the distance is measured in inches, then the torque is read as 12 in.-lbs.

Torque wrenches for applying the proper amount of torque to fasteners are available in four basic forms: The *dial type* incorporates a calibrated dial that indicates by pointer when the desired torque is being applied. The *clutch type* has settings calibrated on the handle with a knurled sleeve for setting to the desired torque (drive is disengaged or slips when proper torque is reached). *Direct reading pointer types* employ a calibrated scale with pointer rod attached to the handle head that indicates torque in direct readings on scale. The *click type* unit produces an audible sound when preset torque force is reached. Some models are available with reversible ratchet, allowing the same handle to be used for general assembly without the need for switching tools.

Sometimes adapters of various shapes must be used with a torque wrench to get around obstructions. If the adapter is in effect only an extension bar, with the drive and hex parts in line with each other, then the torque readings will not be affected. However, if the adapter is similar to an end wrench, in effect making the torque wrench longer, then the torque readings will have to be corrected, depending on how long the adapter is. As torque wrenches do have limits, they are made in a variety of sizes to accommodate all of the limits. Tiny ones

1. Dial indicator on Milbar torque wrench is shown hovering around the 120-in.-lbs. or 10-ft.-lbs. level. This sensitive tool is used in critical areas where precise tightening is mandatory.

2. The offset design of a distributor wrench is a big help in reaching those buried mounting bolts in today's overloaded engine compartments.

3. Restoring stripped threads (like blind spark plug holes), calls for drilling, tapping, then inserting Heli-Coil-type threads to restore the hole to its original size.

4. Breaking a cap screw off in a block or cylinder head always ends in a sweat. First try to remove the residual piece by tapping it with a chisel or a punch. It should unscrew from the hole. If that doesn't work, you can use an extractor or drill out the old bolt and re-thread the hole.

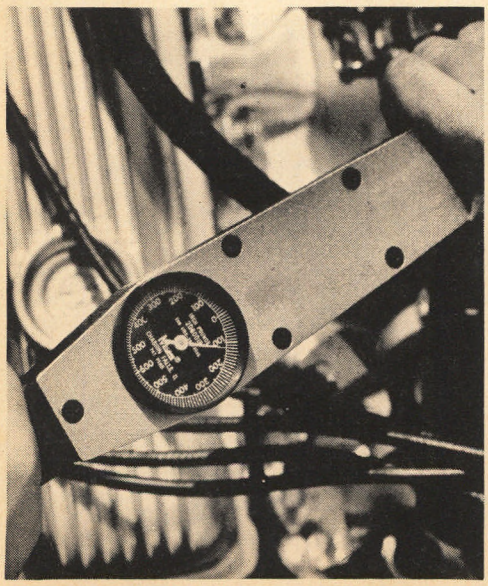
5. As basic to the toolbox as the screwdriver, pliers come in all shapes and sizes. For instance, we've shown (top row, from left) bent needle nose, and diagonal wire cutters; (bottom row, from left) lineman, a pair of double-jointed types and a needle nose.

6. Continental American's standard screwdriver set is ideal for most automotive work. It features both standard and Phillips head tips, various lengths and blade widths.

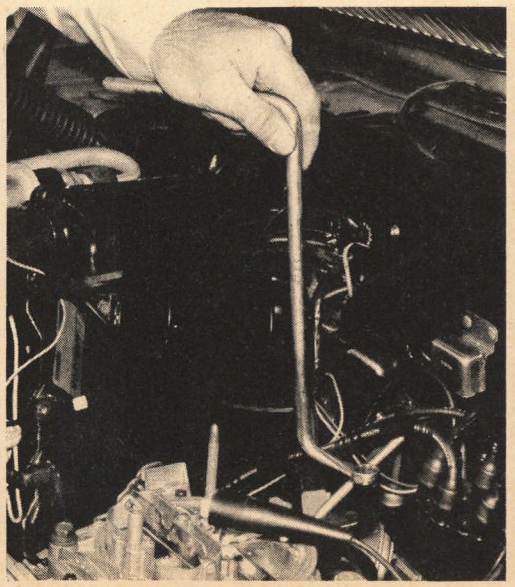
7. Spark plug-type tire pump fits into spark plug well and pumps up to 105 psi of clean air. A 16-ft. hose, connectors and pressure gauge make this an outstanding replacement for older hand pump.

8. No matter what you think, every mechanic needs his hammers. Claw type will pound 'n' pry; round end of the ball peen makes an excellent gasket shaper, and you can always use a soft-faced rubber or plastic headed hammer to tap in parts without marring their machined surfaces.

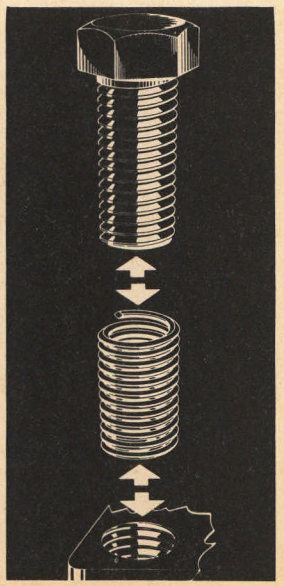
9. This 8-piece hex key set by Craftsman has just about every size from 2 to 10mm that you'll need for automotive work.



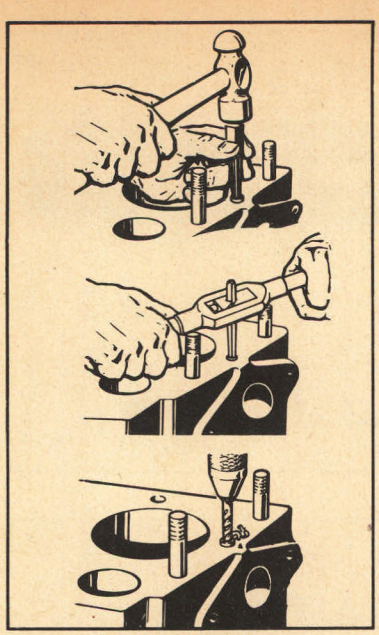
1. Torquing Bolts to Specs



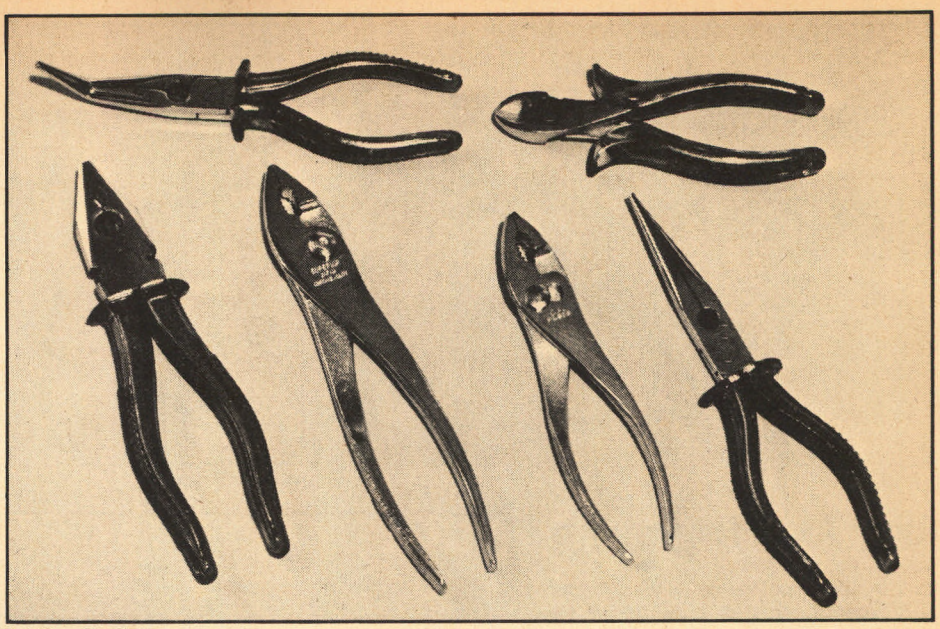
2. Distributor Offset Wrench



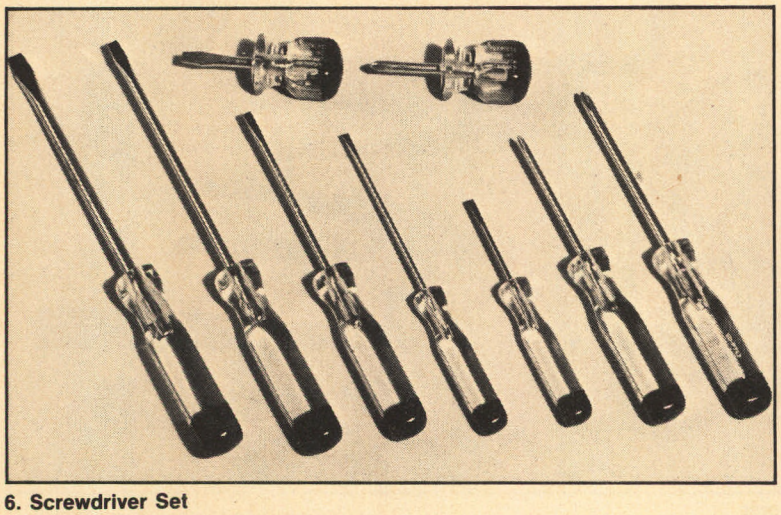
3. Heli-Coils



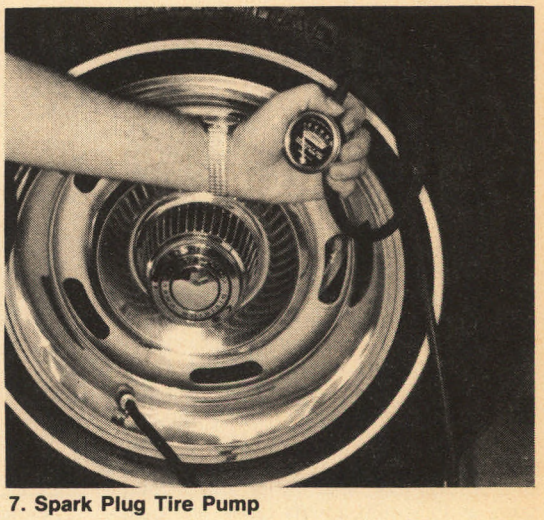
4. Using Screw Extractor



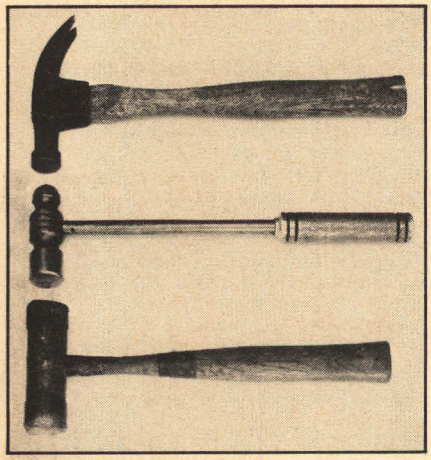
5. Plier Package



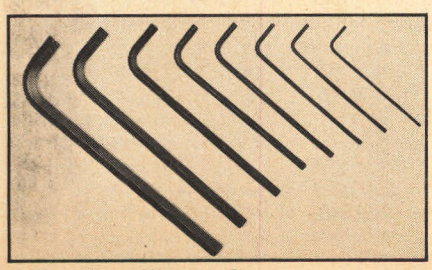
6. Screwdriver Set



7. Spark Plug Tire Pump



8. Types of Hammers



9. Hex Head Wrench Set

for setting fuel injectors have a limit of 150 in.-lbs., while larger handles with higher capacities are required for the 80-150 ft.-lbs. specified for main bearing caps, heads, etc. Heavy-duty ones used on industrial equipment go up to 6000 ft.-lbs. As a rough guide to selection of torque wrench range, here are a few general ratings and applicable common usages:

1) 0-80 ft.-lbs.—⅜- or ½-in. drive.

Spark plugs, intake and exhaust manifold, rocker arm brackets and covers, connecting rod cap bolts, transmission oil pan.

2) 10-150 ft.-lbs.—½-in. drive.

Main bearing caps, cylinder head bolts, main bearings, vibration dampener, transmission pump bolts, connecting rod bearings, power steering pump.

3) 100-500 ft.-lbs.—¾-in. drive.

Main bearing cap bolts, cylinder-head bolts, flywheel, pulley bolts and other jobs on big industrial and commercial equipment.

THREAD SAVERS

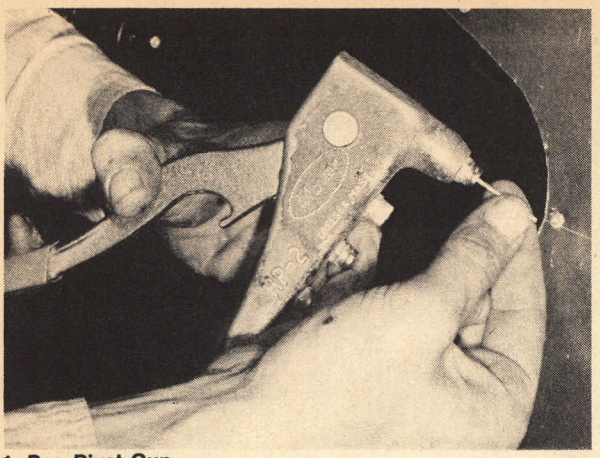
Breaking a bolt inside a threaded hole, or stripping the internal threads, are two major problems with fasteners that are sure to plague the amateur mechanic—they occur quite often even to the trained professional. Stripping threads, especially in aluminum and quite often in the spark plug hole, does not mean the piece must be scrapped, thanks to several handy repair methods.

The two most popular devices for repairing damaged threads in blind holes, spark plug holes, or straight-through ones are the Heli-Coil, made by Heli-Coil Corp., Danbury, Conn., and the Slimsert by Proto Tool Co.

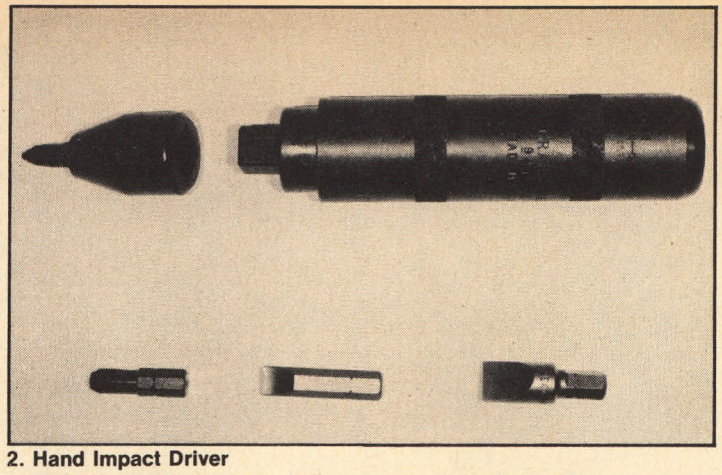
Both require the damaged hole to be drilled out, tapped properly, and then completed by the installation of the new thread assembly. Both are sold in complete kits to handle a variety of sizes and thread patterns, and have the advantage of restoring damaged holes to their original bolt and thread per inch size.

Broken bolts are another serious problem as they almost always break well inside the hole, eliminating the possibility of getting a hold on them with anything. With a little time and effort, and the proper screw extractors, they can be removed without damage to the part other than the cross threading or bottoming that caused the breakage in the first place.

Screw extractors are usually sold in sets, sized to remove anything from ¼-in.



1. Pop Rivet Gun



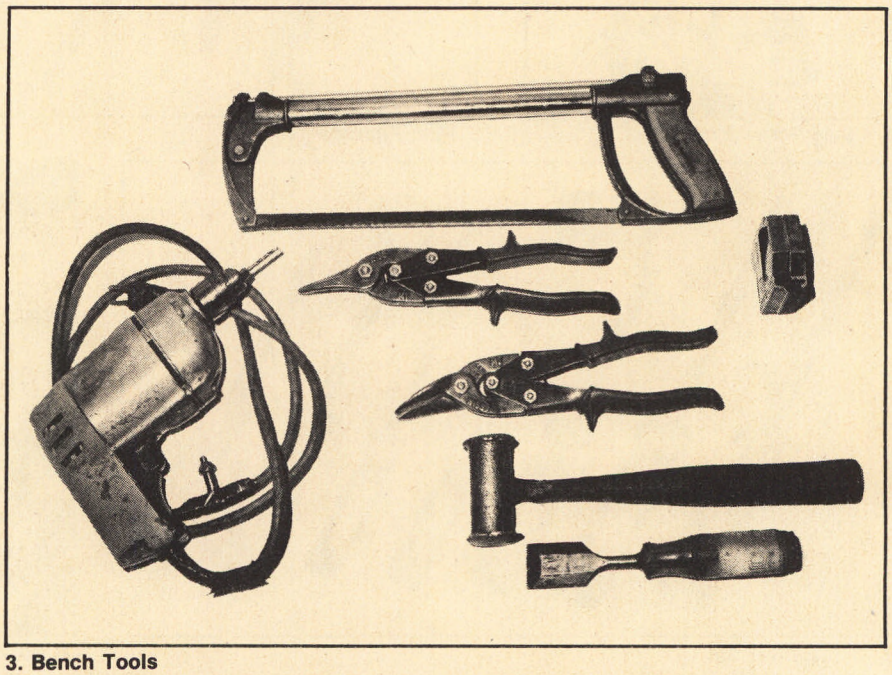
2. Hand Impact Driver

Right Tools for the Job

to 1-in. bolts or studs. They are fluted and tapered tools of high grade steel, sometimes with spiral fluting in a left-hand pattern.

For broken bolt removal it is necessary to drill a hole into the broken piece as near center as possible. The extractor is then driven or screwed into the hole and unscrewed while being held with a tap wrench. Penetrating oil on the broken part will often ease removal, and the internal threads should be examined and repaired before you proceed with any further assembly of the component.

Screw extractors are scorned by many automotive machinists, because they can break off, leaving a problem twice as bad as a simple broken bolt or stud. Broken extractors cannot be drilled out because they are so hard. Many broken bolts can be removed simply by tapping them with a sharp-pointed chisel so that they are unscrewed from the hole. If the bolt or stud has been in the hole a long time, as in an old engine block, the best and safest way to get it out is to drill a hole exactly in the middle of the bolt, and of the same diameter as the threads in the block. If done correctly, the only thing left in the block will be a spiral of thread that can be picked out with a chisel, leaving the threads in the block untouched.



3. Bench Tools

SCREWDRIVERS

The screwdriver is such a basic tool that it hardly seems worth mentioning, but so many repair jobs have been butchered by the improper use of this tool that a few tips are in order. First, the slot in any screw has definite dimensions—length, width and depth. Like a bolt head or nut, the screw slot must be driven by a tool that uses all of the available bearing surface and does not slip. A close look at the blade of a new screwdriver will reveal that the sides near the end are parallel, just like those in the screw slot. When repairing or re-grinding screwdriver blades, remember this: Tapered sides will just wedge the blade out of the slot, reducing the available force and damaging the slot itself. Don't use a big wide blade on a small screw, and don't try to operate a large screw slot with tiny narrow blades. Screws with Phillips heads, Allen heads or hollow hex heads should always be driven with the proper driving tool. Any attempts made with a single-bladed screwdriver can damage these openings to a point where removal is impossible even with the proper tool for the job.

PLIERS

Pliers are about as basic as the screwdriver and few homes are without a pair, but the sizes and shapes available will require some selectivity on the part of anyone starting to assemble a professional set of tools. One tool maker alone lists 29 different types of pliers in his catalog, with sub-selections under certain categories. No mechanic has or needs all of them, and a few carefully selected pieces will cover many jobs.

A good pair of double-jointed, straight-jaw pliers are always handy and some long-nosed ones for reaching into hard-to-get-at places will find ready use on many jobs. Be sure to include a set of diagonal wire cutters as they are indispensable when doing electrical wiring or setting cotter keys. There are also special pliers for brake springs, hose clamps, retaining rings, and the small nuts on distributors and voltage regulators which can be purchased as needed.

1. A hand pop rivet gun is a must if you plan to do any type of sheet-metal fabrication or panel reshaping.

2. Strike this hand impact driver with a hammer and up to 200 ft.-lbs. of pressure turns the bit up to 20°. It's also reversible for loosening frozen nuts, screws or bolts.

3. No mechanic's hand tool collection is complete unless it encompasses a bunch of bench goodies. Hack saws, tapes, an electric drill motor, tin snips, brass hammer and chisels are just a few things needed to make the job that much easier and better.

Two very handy tools are tne Vise-Grip (an adjustable locking plier that stays on when locked and also is capable of a very firm grip) and the parallel-jaw adjustable pliers with angled jaws that stay parallel in any degree of opening. This latter is often referred to as Channel-Lok or water pump pliers and is very handy for grabbing both round and square shapes firmly.

Specialty items that are nice to have but not really necessary are battery terminal and spark plug terminal pliers. The spark plug pliers are heavily insulated and allow the plug terminals to be re-

moved while the engine is running without danger of shocking the user with high voltage.

HAMMERS

Often used with little discretion, hammers are a very important part of the mechanic's tool kit. There is a story that German mechanics forbid their apprentices to even have one in their kit, forcing the student to "fit it, don't bang it." A good ball-peen hammer of medium size, plus a soft-faced one for tapping parts into place without damaging them, are really necessary in most of today's automotive repair work. In addition, special hammers for bodywork are a must if any type of sheetmetal repair is attempted, and the handless hammer or bucking dolly in various shapes should be included in the body repair tool kit to make the job easier.

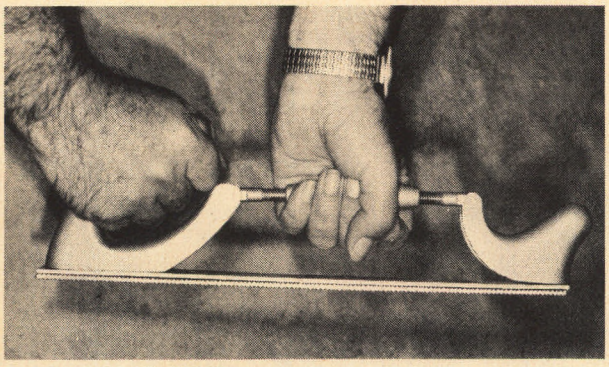
With the multitude of service stations, each with a tire changing jig, it is rare that anyone peels tires off the rims or remounts them by hand anymore. But, just in case the need occurs, a heavy rubber mallet is a must for pounding tire beads back into the rim recess. A rubber mallet also comes in mighty handy when replacing wheel covers; it can assure a tight fit with little danger of denting the covers.

SAWS—FILES—BENCH TOOLS

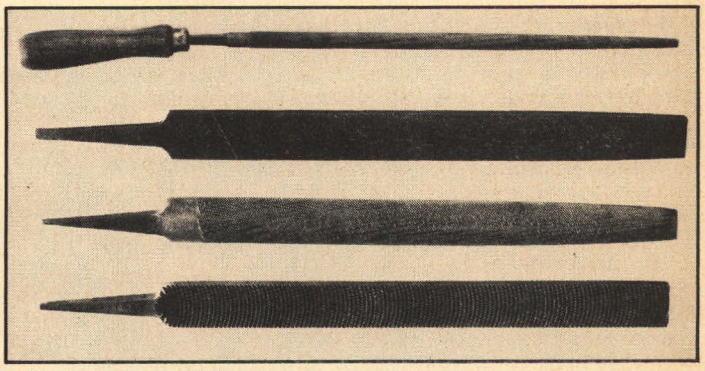
For any kind of automotive repair work, where parts are removed from the car and refurbished at home, a good bench vise is indispensable. Naturally, it should be well mounted on a suitable work table or bench—not necessarily large, but well anchored and capable of handling the usual pounding without giving way. The bench vise should be securely mounted and have at least 4-in. jaws with soft interchangeable inserts for holding parts that may scratch or be indented by sharp hard jaw faces.

A good hacksaw frame, one that will hold its shape and is adjustable for blades up to 12 ins. long, is needed in every tool kit. While they cost a bit more, the high-speed blades are a good investment as they last a long time. For general work one should have a selection of fine-toothed blades, 32 teeth per inch, for cutting harder steels, and some coarser ones in the 18-to-24-teeth-per-inch size for soft materials. One never knows when a bolt must be shortened or a bit of metal cut for a bracket.

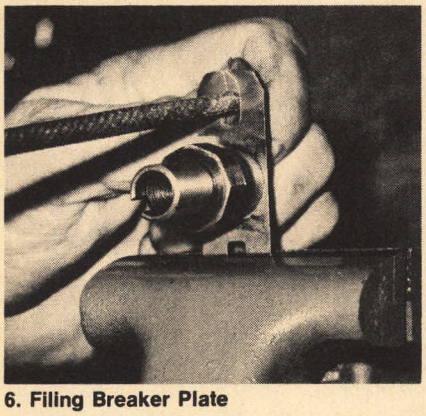
Just about every saw cut must be finished off and a good file, in lieu of a



4. Adjustable Body File Holder



5. Various Types of Files



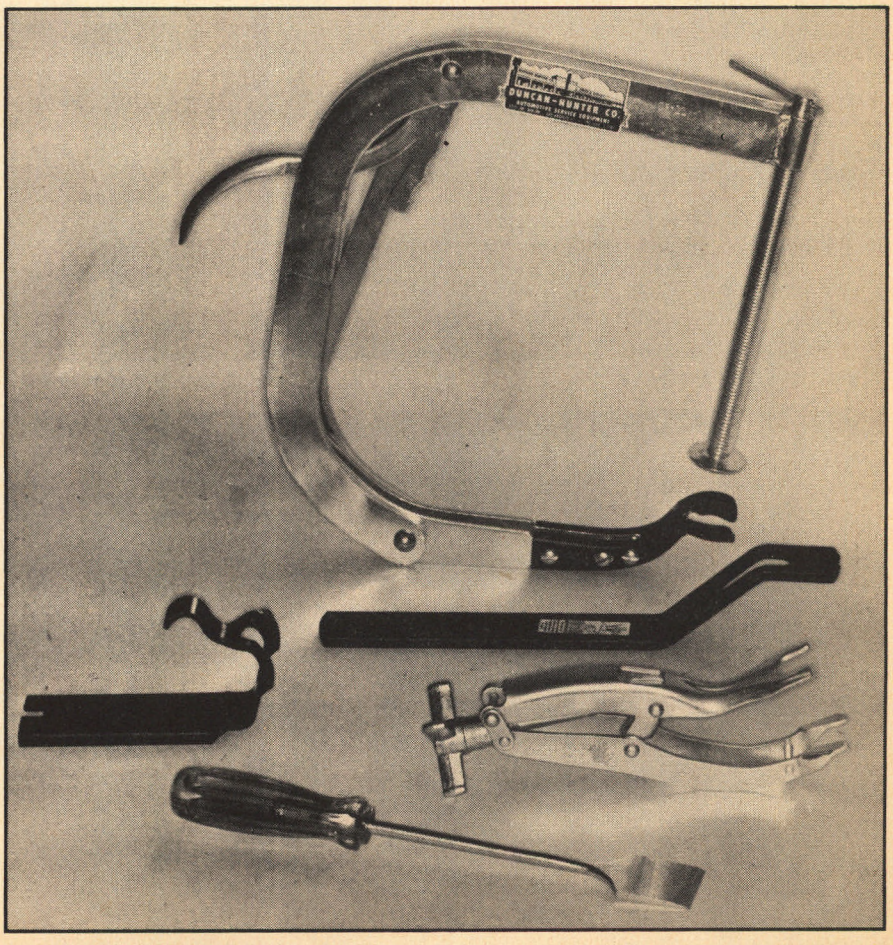
6. Filing Breaker Plate

4. If you plan on doing any metal work, this body file holder will come in handy. One like this Craftsman adjusts for concave, convex or straight filing; just turn the center post.

5. Files should be selected as to tooth—either fine or coarse. Small, fine files are used for delicate work, the large rasps for body repairs. Illustrated here is the basic rattail, flat, half-round and vixen . . . all well used.

6. Rattail file and a good bench vise will almost take the place of a juice-powered bench grinder.

7. Specialized tools, like these various types of valve spring compressors and a gasket scraper, aren't that expensive and are virtually indispensable should you plan to replace a blown head gasket or do your own valve job.



7. Specialized Tools

Right Tools for the Job

bench grinder, is the only answer. Files should be selected the same way as saw blades—some fine toothed, others on the coarse side for softer metals. Included in the file set should be a thin flat-point file for dressing up distributor contacts, plus some slim tapered 3-cornered ones and a round rat tail for cleaning out slots or enlarging and deburring drilled holes.

Any sheetmetal or body shop will require the need for metal shears or "tin snips," and the most versatile are a set of aviation-type shears sometimes called "dutchmen." A full set includes a straight cutter, and a left- and right-hand one since cutting curves is eased by using the one for the direction of the cut—*i.e.*, left or right direction. These are also great for trimming exhaust tubing in the final fitting stages when making custom headers or exhaust systems to suit special needs.

If bodywork is your project, several additional special files should be added to the kit. These come in flat and half-rounded cross sections, have curved teeth more like a series of blades, and are used in a holder that curves them to suit conditions. Indispensable for smoothing or skinning sheetmetal or leaded portions of repaired sections, they are a valuable tool for any kind of bodywork, amateur or professional.

SPECIAL TOOLS

Many automotive assemblies and components require special tools to adjust or repair. One of the most specialized in this area is probably automatic transmission band adjustment. Universal sets for doing this type of work are available in complete form and include the necessary gauges, short-handled end wrenches, a band-adjusting T-handled tool, and complete torque setting chart for all types of automatics. A short-handled torque wrench is needed with a ¼-in. drive and a 0-150 ft.-lbs. range, but if such a tool is already a part of the kit, the additional pieces for doing such work can be purchased as needed.

Front suspension repair, especially wheel alignment work, will require special tools for certain cars due to the dif-

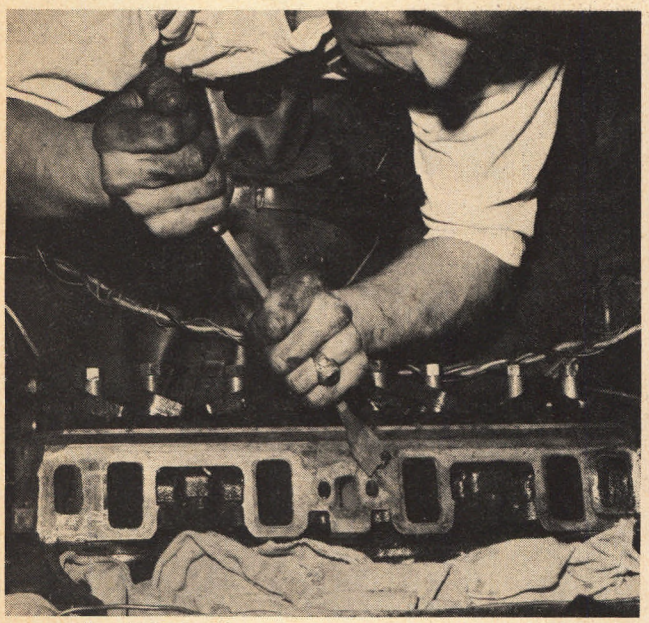
1. The machined surfaces between the cylinder head and intake manifold must be free of old gasket material and cinching compound if the new gasket is to seal properly. You can always use a large screwdriver or a putty knife for this cleaning operation, but a scraper is better.

2. Fully adjustable pullers are "the only way" to force the gear off the end of the crank. If you try it with a hammer, punch or chisel, you'll raise heck with the main bearings.

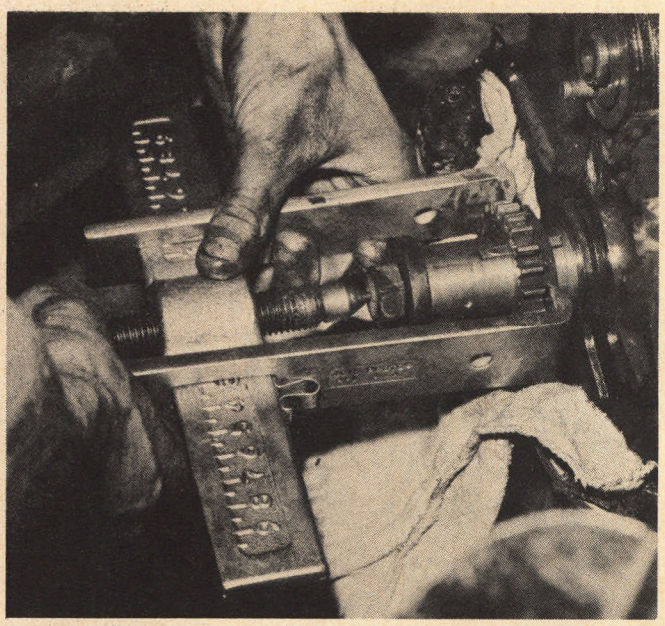
3. While water pump pliers will suffice, hose clamp pliers with specially milled jaws make pulling the rings off the hoses a snap.

4. If you plan to work under your car, you'll need a set of axle stands. Too many people have been killed or badly hurt trying to make a bumper jack take the place of stands or a hoist. Stands aren't expensive.

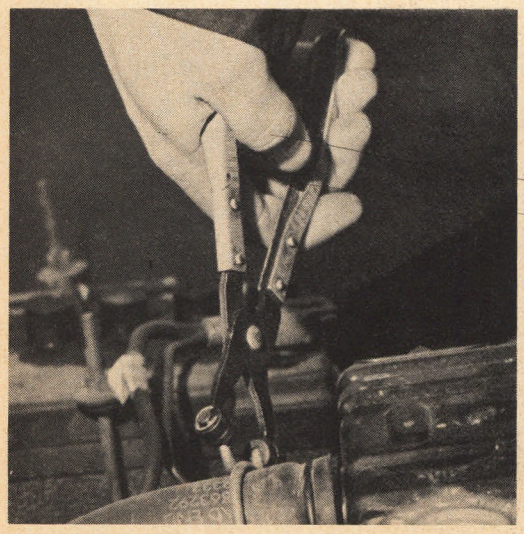
5. Drill motors, hones, wire brushes, stones, drills, etc., become an outfit a mechanic cannot afford to be without. Most quality ¼-in. drives will cost around $25-$30.



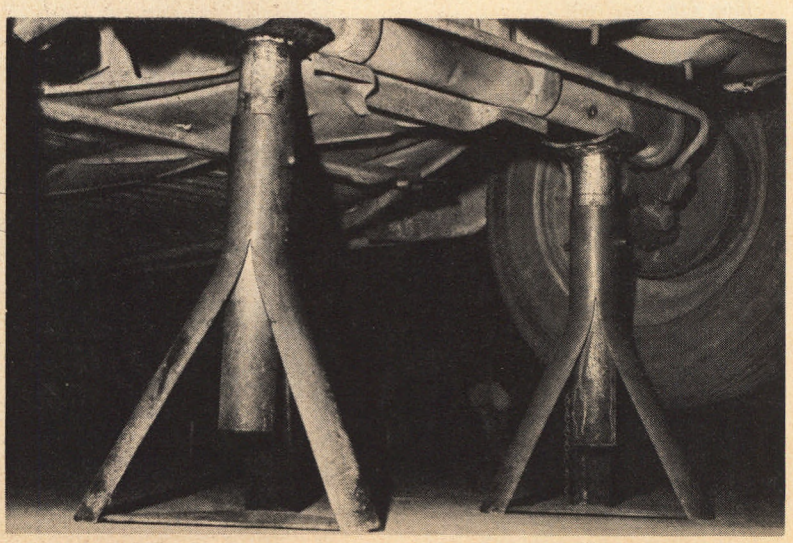
1. Scraping Cylinder Head



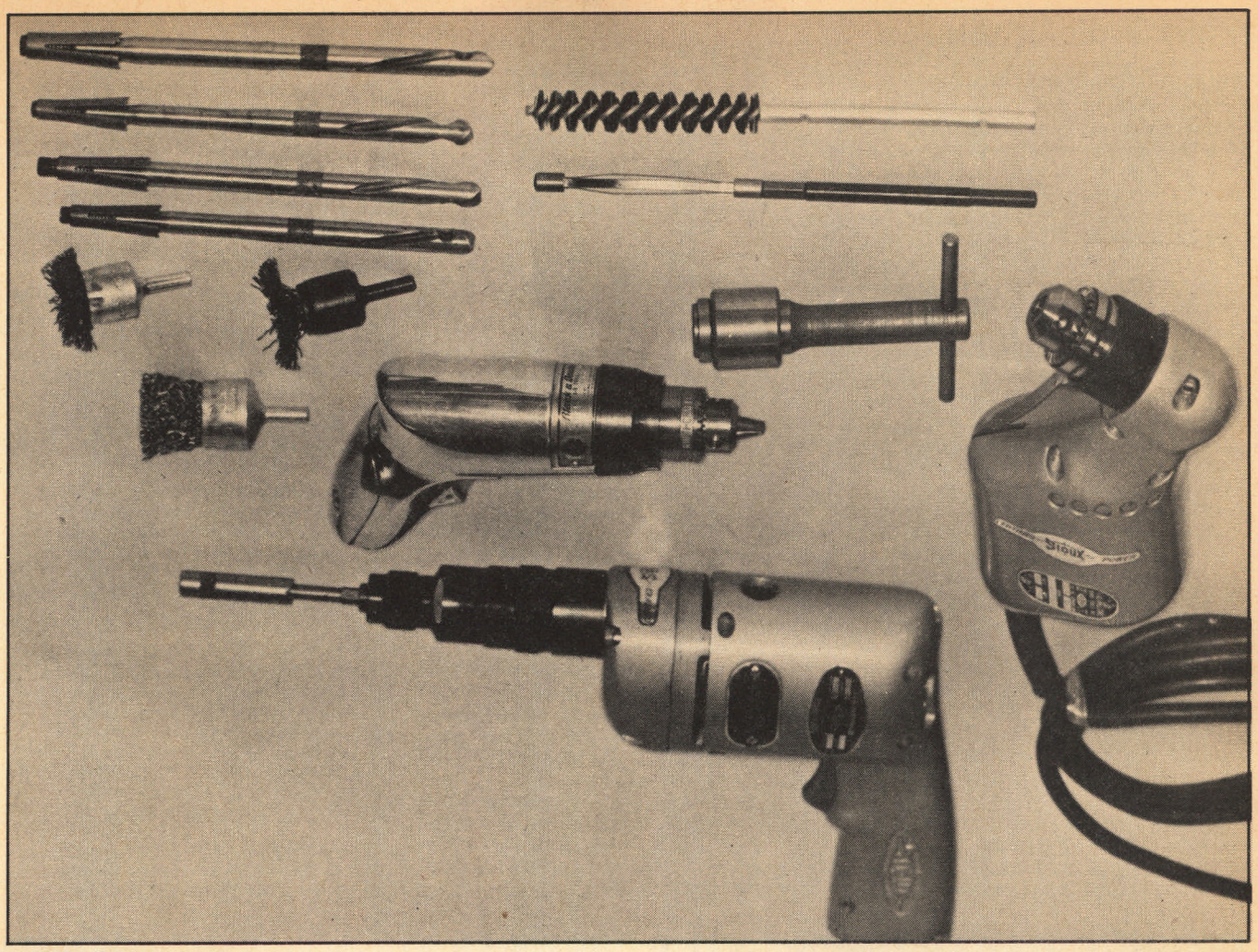
2. Pulling Crank Gear



3. Depressing Hose Clamp



4. Jack Stands



5. Power Tools

ficulty in getting standard wrenches into some of the tight spots. Most tool makers have such special tools designed for cars with these special requirements.

Similar special handle shapes are available for reaching hard-to-get-at hold-down bolts on both front- and rear-mounted distributors. While not absolutely necessary, they certainly can speed up access to these fasteners through the maze of ignition wires and other under-the-hood plumbing.

The correct bleeding and adjusting tools will make these repair and maintenance jobs a lot simpler, allowing better concentration on the work itself without knuckle busting. Valve adjusting for mechanical overhead systems is best done with a combo-tool that uses a ½-in. drive socket for loosening the lock nuts and a knurled knob that actuates a screwdriver down through the socket for turning the adjusting screw.

Anyone doing brake or fuel line work will need a tubing cutter and a double flaring tool. These will cut and flare properly all types of steel and copper tubing for hydraulic, fuel and oil lines and are the only things for a first-class job of cutting to size without distorting the tubing, and flaring properly for leakproof and permanent joints.

Many a job has been bungled and expensive parts damaged because they were dismantled by pounding rather than by the use of a proper puller. There are a variety of these, both the screw-actuated type and the impact type. Timing gears, wheel hubs, harmonic balancers, axle shafts, bearings, steering wheels, blind pilot bearings, and even battery terminals often require the use of a special puller to separate them from their related shafts or mountings. In this classification are also stud removers, and while not employing exactly the same principles as a 2- or 3-jaw screw or impact puller, they operate by securely grasping the stud in a wedging manner, allowing it to be backed out in one piece by either socket handle drive or impact wrench.

In addition to the appropriate set of wrenches, sockets, etc., any engine overhauling—even a simple ring and valve job—will require a piston ring compressor of the adjustable type for inserting the newly ringed pistons without breaking the rings. Also included in this tool selection should be a valve guide cleaner, gasket and carbon scrapers, a valve lifter clamp for depressing the springs for removal of keepers, and a grinding tool for lapping the valves to the seats for a leakproof seal.

Glaze-breaking hones, ring groove cleaners, and small cylinder hones for brake overhauls will be necessary for the do-it-yourself mechanic as he expands his efforts into more complicated repair operations.

One can save a lot of money by checking first the tools needed for the job on a particular car and then shopping the parts supply houses for just the minimum required. Tool makers supply tools in kit form for various special parts of the car such as front end, transmissions, distributors, brake service, as well as bushing, seal installers, etc. Check these to see if the present tools will do the job before investing in tools that may only duplicate what is already in your kit.

POWER TOOLS

About the only power tool the home mechanic will find unlimited use for is a ¼- or ⅜-in. drill. These are available in a variety of qualities and prices, and those offered for the home mechanic are adequate for the average user for both drilling and honing. Industrial grades, made for the hard use of the professional, naturally cost more, but in recent years, many of the top power tool makers have designed power tools of all sorts well within the budget of the home craftsman. Try these before investing in extra heavy-duty industrial tools built to last several lifetimes of occasional use.

A good set of bits for the power drill will be a necessity, and the high-speed type is the best investment. There is not much point in buying a set larger than the chuck will accommodate, so govern the size of the set by this standard. Drills come in two basic sizes: number drills and fractional drills. The number drills go in sizes up to No. 1, the largest (.2280-in.), to the smallest, No. 80

Right Tools for the Job

(.0135-in.). There is a limit as to how small a drill can be safely used in a hand-held power drill, so this should be considered when selecting the set. There are also fractional drill sizes ranging from 1/16-in. to 1/2-in., in increments of 1/64th of an inch. The number drill series include letter sizes, A-B-C, etc., commonly used for tap drill holes larger than the No. 1. Whatever drill system is selected, purchase those that come in a metal case as this will aid in keeping the set complete and avoid loss—somewhere in the toolbox—of just the one you need.

If one has the budget and the need, he will find many uses for a bench grinder in the home shop. Sharpening tools, buffing, and wire brushing, to name a few, are easy jobs with a grinder.

Impact wrenches, mentioned earlier, come in both electric and air drive. For the latter, one needs a compressor and air storage tank, and if the shop is so equipped, say for spray painting, etc., then an air drive is a good investment. The smaller heavy-duty models are capable of tightening up to 200 ft.-lbs. of torque, while the equivalent electric drives impart up to 130 ft.-lbs. While standard ½-in. drive sockets can be used for lighter work, it is recommended that the special heavy-duty wrenches and adapters be used for impact wrenches because of the rather sharp blows imparted to the tools.

Body repair work or any kind of sheet-metal modifications will require a heavy-duty disc sander. These are used by professional body workers for everything from rough metal removal to final polishing of the painted and waxed surface. In addition, a vibrating-type sander for fine metal finishing and preparing bare or primed surfaces for painting is a must unless one is ready to spend needless hours doing these chores by hand.

TEST INSTRUMENTS AND MEASURING TOOLS

Every mechanic's toolbox should contain a set of flat steel feeler gauges, plus the round wire type for checking plug gaps. There are regular plug gap gauges that have all of the most common dimensions in addition to a device for bending the outside electrode. The flat feeler gauges are needed for point adjustment and valve rocker settings. For extensive repair and rebuilding of master and wheel hydraulic cylinders, an inside measuring kit is available consisting of a handle and a set of go, and no-go, gauges for determining the exact inside bore diameter of these cylinders.

Micrometers—inside, outside and depth—are needed for just about any major engine overhaul to accurately check bore, bearing diameters, and deck clearances. These will have to be purchased in sets, as no one tool will give the range of measurements needed for automotive work. Outside micrometers have only about 1 in. of range without special adapters, but some are available in sets that will handle everything from 1 to 4

1. Spark plug gapping tools should always feature an adjustment hook, round wire gauges and a fine tooth file. Forget tapping the side wire on the cement. Flat feeler gauges won't get an accurate reading.

2. Drill is perfect for chamfering oil holes or for removing flashing from the inside of a cylinder block.

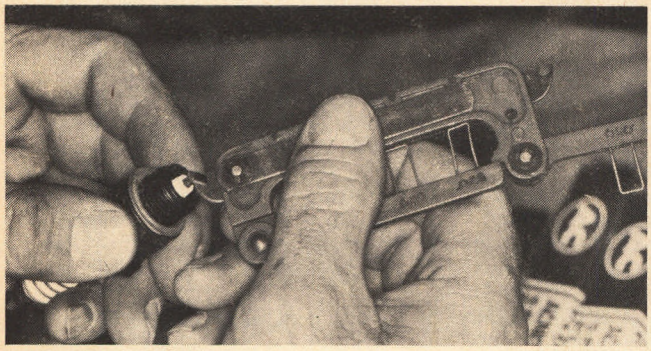
3. Drill motors can power anything from bits to brushes. If you don't need 'em to cut some holes to mount a bracket, they'll come in handy for buffing out a lacquer paint job.

4. Impact wrenches are expensive, but are quick and efficient. Most amateurs rely upon electric models rather than the compressed air type. Sockets are 6-point types.

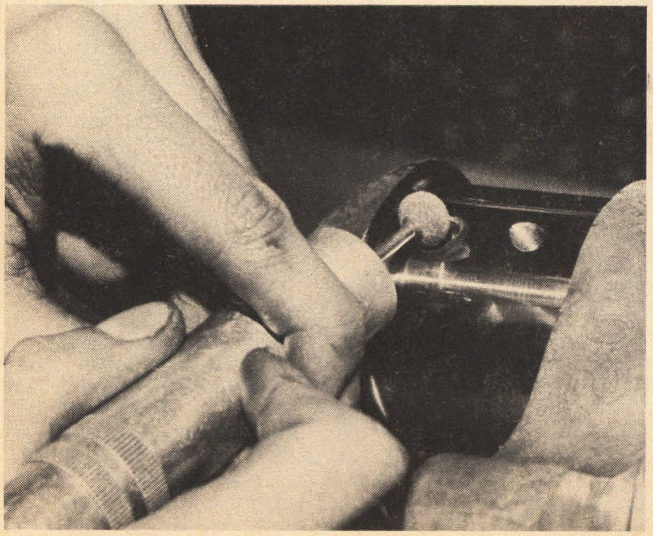
5. For anyone attempting to overhaul an engine, precision measuring devices such as inside, outside, and depth mikes are a must. Included in the precision toolbox should be a dial indicator, steel scale, and a vernier slide caliper.

6. The simple compression gauge or tester is used to measure how much chamber pressure engine can build. Pressure differential (from cylinder to cylinder), not total amount, is what's important . . . and so is how you hold the tester to the plug hole. The seal must be good or you'll receive a misleading reading.

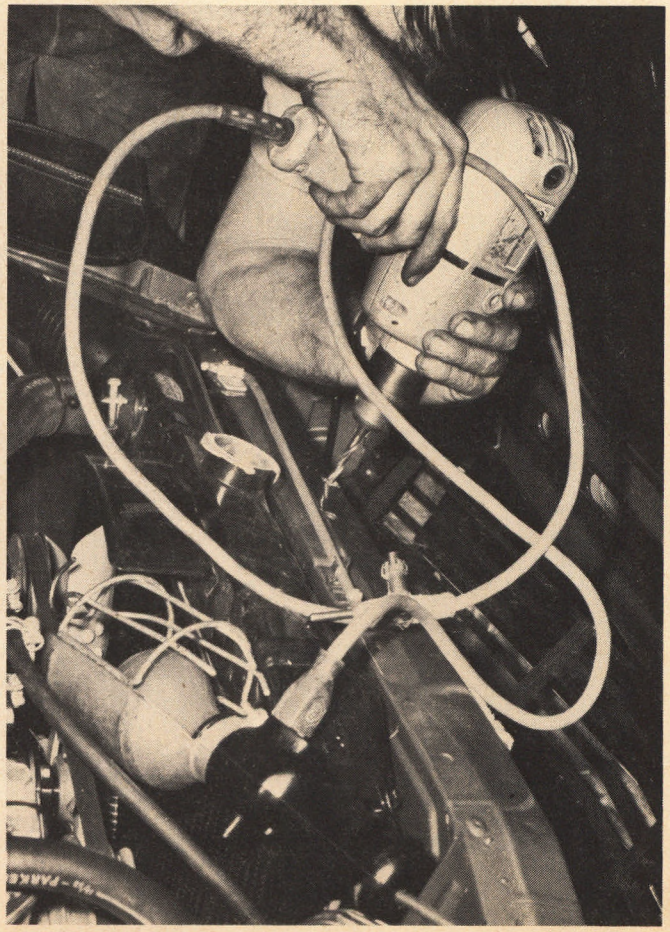
7. No backyard tune-ups or engine timing should be attempted unless you have a strobe timing light.



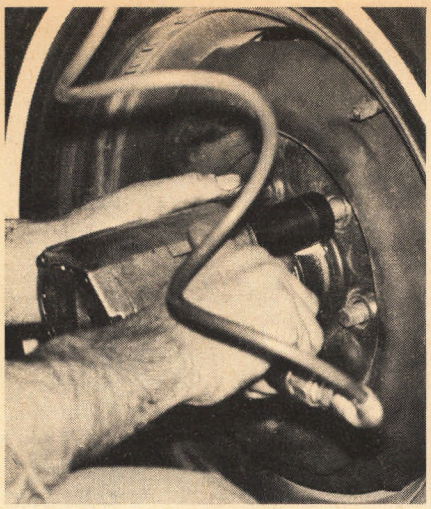
1. Gapping Spark Plugs



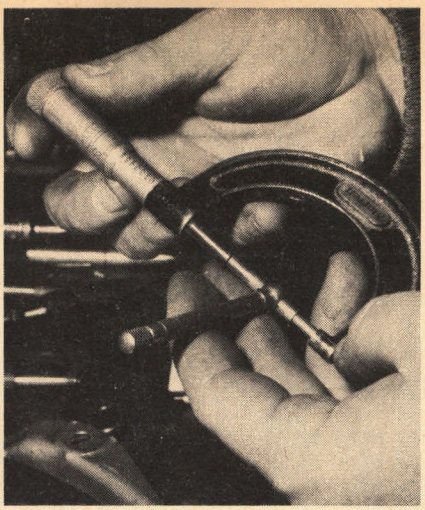
2. Chamfering Oil Holes



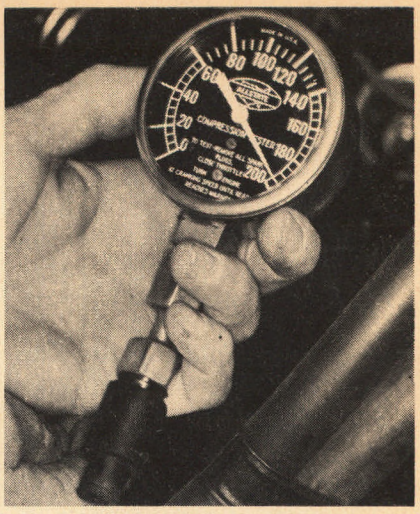
3. Drilling Holes



4. Removing Lug Nuts



5. Using Inside/Outside Mike



6. Testing Compression

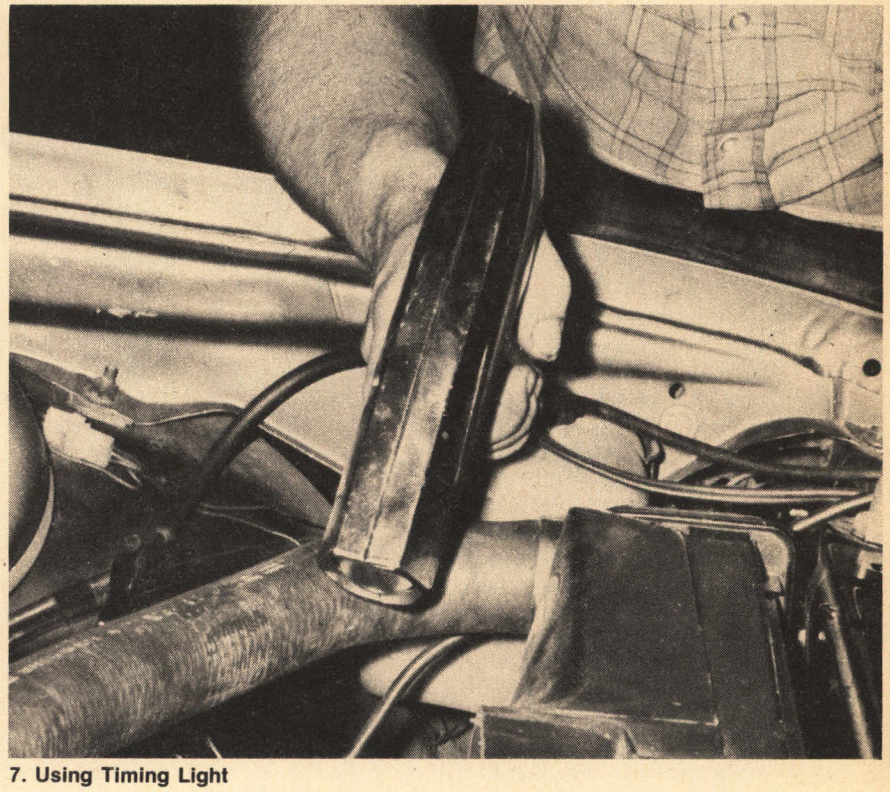
ins. The same is true of inside micrometers and ones used for depth measurement. Learning how to read micrometers takes a bit of study so it is a good idea to become familiar in dealing with the .001-in. measurements before doing any serious work with them. Some micrometers have a built-in vernier so they can measure to tenths of thousandths. For quick measurements to thousandths, or even to tenths, a vernier caliper is handy to have.

Another measuring device is the brake drum and shoe gauge, which is used to detect both drum wear and diameter and to set up shoes on the backing plate. While this gauge is available from tool supply houses, most new car and brake repair shops will have it as a shop tool, not necessarily in the individual mechanic's kit. This is a modest cost tool that one should have for doing serious brake repair or overhaul.

There is a gauge or instrument for testing just about every component of an automobile. The list is long and mostly expensive: Automatic transmission oil pressure, vacuum, engine oil pressure, headlight candlepower, engine coolant temperature, fuel pressure, battery specific gravity, electrical resistance, voltage, current, engine speed, and on and on—an endless number of devices not including wheel alignment and balancing, that are available for automotive measuring, testing and repair work.

For serious engine tune-up and ignition work, the home mechanic's kit should include some kind of continuity tester for tracing out broken circuits, a voltmeter, and a power timing light. Simple volt/ohm ammeter and continuity testers can be purchased at radio supply houses, and many suppliers of automotive ignition testing equipment stock everything from simple meters to very sophisticated multiple units for checking everything electrical.

Continuity lights in the form of plastic-housed glow tubes with a probe and wire clip are modestly priced units that are worth the investment. One can make a simple test light by soldering a pair of wires to the proper contacts of a tail or parking light socket, terminating the loose ends to alligator clips or probes, and using a 12-volt bulb in the socket. This is an excellent light for setting initial spark timing by the "points-just-opening" method with the engine dead.



7. Using Timing Light

A strobe timing light is used for final ignition timing according to timing marks on the flywheel or vibration damper. They employ a flash or strobe tube that gets its trigger from the ignition high-voltage side. As the light flashes only on the high-voltage impulse, the timing marks apparently stand still while the engine is running, allowing an accurate visual setting of the distributor to the proper timing. One of these should be in every mechanic's tool kit for keeping the ignition in proper adjustment and diagnosing problems.

One of the handiest instruments for checking engine condition is the compression gauge. This comes in various forms, from the simplest one that is held in the spark plug hole while direct readings are noted on the scale, to the more expensive ones with flexible hose, screw-in spark plug fitting, and tell-tale needle that stays at the highest reading until released. Both do a good job of reading the combustion chamber pressures; choice will depend on the size of your pocketbook.

Car clubs often find that pooling of funds allows the purchase of the more expensive instruments, justified by more use than the individual home mechanic would ever find practical unless he had unlimited funds. Some of the electrical analyzers are great time savers and allow more accurate adjustment of everything from dwell to fuel pump pressure.

One of the best ways to keep and protect a set of tools is to store them in a locked steel toolbox. Tools have a way of disappearing when left around loose, and a lock-type box of adequate size is a good investment. The choice is unlimited and goes all the way from a small kit to a large roll-away. Whatever the choice, anticipate that more tools will be added from time to time, so buy one larger than is needed at the moment and grow into it rather than out of it.

Basic Tool Set Checklist

Whatever your reasons for buying tools—for the sheer enjoyment of neat equipment or the necessity to save money on repairs—you do have to start somewhere, and this is where the neophyte can get confused on his first trip to the store. We've compiled a starter's list of tools and several lists of optional tools, according to the "difficulty level" of the work you intend to do. You may start out with simple things and when your confidence increases, move on to more challenging jobs that require different and more specialized tools.

We haven't listed *all* the tools you might ever need, for this could fill the entire book, but there are many tools that are seldom used by the home mechanic. Our starter list includes the most commonly used hand tools for weekend work on your car. There will be many other tools that you *may* need for specific, specialized jobs, but the ones mentioned here are ones that you certainly *will* need for almost any job you undertake.

Each list—the starter set and the optional ones—is in sequence. In other words, if you do only average, small repairs the starter set will get you by, but for changing your own oil and home lube jobs, you'll need the maintenance set. Each optional set of tools we have listed relates to an ascending order of job difficulty. For instance, tune-up work would be harder for the amateur than maintenance, brake jobs would be harder than a minor tune-up, and of course major engine work would be more difficult than the others.

Within each set of tools, we have listed them in the order in which you should purchase them, realizing that not everyone can afford to run out and buy a complete tool set right away. You will likely need all the tools in a particular set at some point in time, but you can get by for a while without some.

In our basic set, we have two jack stands listed ahead of the scissors jack; this is because on a budget you could get by with your original car jack until you could afford a scissors or hydraulic one. Similarly, in the brake work list, we put the shoe hold-down-spring tool near the end because you could still do a brake job without it, using pliers instead, until you could afford the right tool. The spoon is listed first, as it is the only tool required to do a simple brake adjustment. Next in difficulty would be bleeding brakes, and the tool listed as No. 2 is the tool you'd need for that job. After that you're into a complete brake job with the rest of the tools indicated.

Shop around for all your tools and don't assume you have to buy all of the same brand, although if you find a good set on sale at Sears or Montgomery Ward, for example, you may experience a savings over buying the tools individually. Most American-made tools carry a very long (or lifetime) guarantee, and used as they were intended, they will indeed *last* a lifetime, too.

(For more information on advanced tools and test equipment, refer to Petersen's line of tool books on those particular subjects.)

Basic Starter Tools

1. Combination box-and-open-end wrenches, from 3/8-in. to 3/4- in. in increments of 1/16-in.
2. 3/8-in.-drive socket set, with ratchet and T-handle
3. 3/8-in-drive spark plug socket and three extensions—a short one, a long one, and a Flex-drive
4. Four screwdrivers, one short and one long of both the Phillips type and the regular, flat-tip type
5. Pair of slip-joint pliers
6. Adjustable wrench (Crescent type)
7. Roll of mechanic's wire (cheap and very handy at times)
8. Diagonal cutting pliers
9. Small stock of sundries, like electrical tape, WD-40 oil, engine degreaser, white-grease lube, and spray-can paints
10. Ball-peen hammer
11. Two jack stands
12. Scissors jack (better than bumper jack, but not as expensive as a hydraulic jack)

Options for Routine Maintenance

1. Battery post and cable terminal cleaner
2. Drain pan for oil and water
3. Wrench for removing spin-on oil filters
4. Hand-operated grease gun
5. Antifreeze tester
6. Spray can of silicone lube, can of wheel bearing grease
7. Mechanic's creeper

Options for Tune-Up Work

1. Spark plug gap setter
2. Flat feeler gauges (for non-GM cars)
3. Small tube of distributor cam lube
4. Carburetor cleaner (spray can or liquid)
5. Ignition timing light
6. Wrench for distributor hold-down bolt (for cars with distributor at rear of engine)
7. Set of small ignition wrenches
8. Hand-held dwell/tach meter
9. Combination vacuum/fuel pressure tester
10. Compression tester

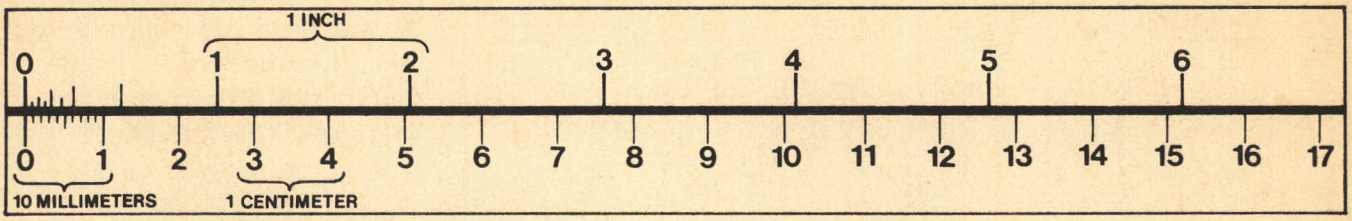
Options for Brake Work

1. Brake adjusting "spoon"
2. Offset-shank brake bleeder wrench
3. Combination remover/installer for shoe return springs
4. Wheel cylinder/master cylinder hone (must be used with an electric drill motor)
5. Combination remover/installer for hold-down springs
6. Two more jack stands

Options for Major Engine Work

1. 1/2-in.-drive socket set with ratchet and breaker bar, plus long, short and flex-type extensions
2. Gear puller
3. 0-100 or 0-150 ft.-lb. torque wrench (1/2-in.-drive)
4. Valve-spring compressor
5. Ring compressor
6. Engine cylinder bore hone (must be used with slow-speed electric drill motor)
7. Ridge remover

NUTS, BOLTS AND SCREWS



METRIC INFORMATION

We will briefly discuss the metric system, in case you're not familiar with it and its broadening use throughout the United States in the past few years.

Units of weight and measure are a language between individuals, companies and countries. If clear definitions of these standards do not exist, fraud in commerce and a general lack of reliability in technical communication will exist.

Measurement systems evolved over a period of years among the scientists and philosophers of Western Europe. The systems which came into being in Europe were similar but uncorrelated. The metric system became a reality in 1793 when the National Assembly of France adopted the provisional metric system.

The unit of linear measure was known as the meter. It was the equivalent of one-ten-millionth part of the meridian quadrant of the North Pole to the Equator; this meridian passes through Paris. It is a testimony to the skill of the scientists of that period that they were able to determine the length of this quadrant to a high degree of accuracy. They accomplished this by measuring the distance between Dunkirk, France and Barcelona, Spain, which are reasonably close to the meridian passing through Paris.

The use of the metric system in the United States was legalized in 1866, and on May 20, 1875 the United States became a signatory to the so-called "Treaty of the Meter," which established the International Bureau of Weights and Measures in Paris.

Today only the United States and a few countries within Africa are using the English or United States measurement system. All other countries of the world are using, or have changed to, the metric system of measurement. In 1958, India changed to the metric system. In 1965, England began its change from the "Imperial" system to the metric. In 1970, Australia and Canada became metric bound.

In 1968 the United States began a study of the possibility of a changeover to the metric system of measurement. The cost would be unbelievably high. New size standards would have to be developed for nuts, bolts, screws, wire, gears, containers and all related tooling. (Example: changes in standard bolt sizes would require re-analysis of required stress levels and torques; and a review of assembly clearances, flange widths, new drills, taps, dies, gauges, etc., would be required.) This would be the most expensive way to go. The least expensive method would be to re-express all dimensions in terms of metric units with no actual changes in sizing (until manufacturing could catch up and a progressive changeover made).

Even with this "less costly" changeover, a revision of technical literature, tables, documentation, replacement or reworking of calibrated machine tools and, of course, a comprehensive, nationwide educational program would have to be implemented, all at great cost. Complications involved in remembering conversion factors and dealing with odd relationships would require an unnecessary loss of time and be a source of computational errors.

These are just some of the problems which would be encountered in changing our system of weights and measures. The Society of Automotive Engineers (SAE) is attempting to help make the changeover a little easier by providing education in the fundamentals and application of the metric system.

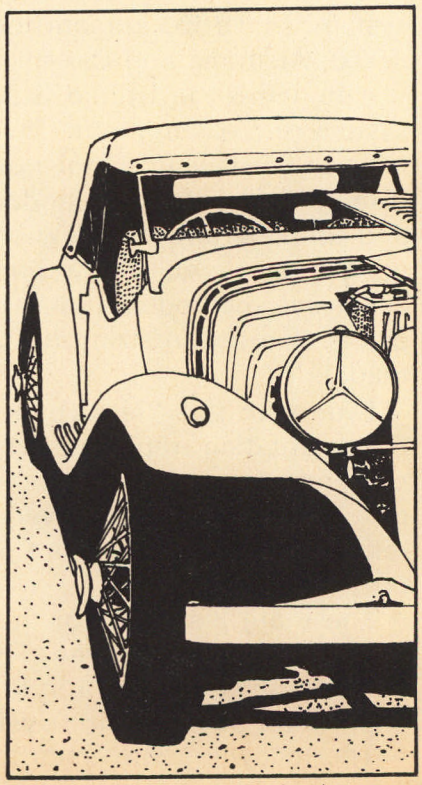
The following conversion tables will aid greatly in using the metric system:

COMPARISON OF U.S., METRIC AND WHITWORTH WRENCH SIZES

U.S.	METRIC	WHITWORTH	DECIMAL INCHES	OPEN-END WRENCH		BOX-END OR SOCKET WRENCH	
NOMINAL NUT SIZE				MIN.	MAX.	MIN.	MAX.
5/32			.156	.158	.161	.158	.163
	4mm		.157	.159	.162	.159	.164
		7BA	.172	.174	.177	.174	.179
3/16			.187	.190	.193	.190	.195
		6BA	.193	.195	.198	.195	.200
	5mm		.197	.199	.202	.199	.204
13/64			.203	.205	.208	.205	.210
7/32			.218	.221	.224	.221	.226
		5BA	.220	.222	.225	.222	.227
15/64			.234	.236	.239	.236	.241
	6mm		.236	.238	.241	.238	.243
		4BA	.248	.250	.253	.250	.255
1/4			.250	.252	.255	.252	.257
17/64			.265	.268	.271	.268	.273
	7mm		.276	.278	.281	.278	.283
9/32			.281	.284	.288	.284	.290
		3BA	.282	.284	.288	.284	.289
5/16			.312	.316	.320	.316	.322
	8mm		.315	.317	.321	.317	.322
		2BA	.324	.327	.331	.327	.333
		1/8W	.338	.341	.345	.341	.347
11/32			.343	.347	.351	.347	.353
	9mm		.354	.357	.361	.357	.363
		1BA	.365	.368	.372	.368	.374
3/8			.375	.378	.382	.378	.384
	10mm		.393	.396	.400	.396	.402
		0BA	.413	.416	.420	.416	.422
	11mm		.433	.436	.440	.436	.442
7/16			.437	.440	.444	.440	.446
		3/16W	.448	.451	.455	.451	.457
15/32			.468	.472	.476	.472	.478
	12mm		.472	.475	.479	.475	.481
1/2			.500	.504	.508	.504	.510
	13mm		.512	.516	.520	.516	.522
		1/4W	.525	.529	.533	.529	.535
17/32			.531	.535	.539	.535	.541
	14mm		.551	.555	.559	.555	.561
9/16			.562	.566	.570	.566	.573
	15mm		.591	.595	.599	.595	.601
19/32			.593	.598	.602	.598	.604
		5/16W	.600	.604	.608	.604	.612
5/8			.625	.629	.633	.629	.636
	16mm		.630	.634	.638	.634	.642
21/32			.656	.661	.665	.661	.668
	17mm		.669	.673	.677	.673	.681
11/16			.687	.692	.696	.692	.699
	18mm		.709	.715	.720	.715	.723
		3/8W	.710	.715	.720	.715	.723
	19mm		.748	.753	.758	.758	.761
3/4			.750	.755	.760	.755	.763
25/32			.781	.786	.791	.786	.794
	20mm		.787	.792	.797	.792	.800
13/16			.812	.818	.823	.818	.826
		7/16W	.820	.825	.830	.825	.833
	21mm		.827	.832	.837	.832	.840
	22mm		.866	.871	.876	.871	.879
7/8			.875	.880	.885	.880	.888
	23mm		.906	.911	.916	.911	.920
29/32			906	.911	.916	.911	.920
		1/2W	.920	.925	.930	.925	.934
15/16			.937	.944	.949	.944	.953
	24mm		.945	.950	.955	.950	.959
31/32			.968	.975	.981	.975	.984
	25mm		.984	.990	.996	.990	.999
1			1.000	1.006	1.012	1.006	1.015
		9/16W	1.010	1.016	1.022	1.016	1.025
	26mm		1.024	1.030	1.036	1.030	1.039
1-1/16			1.062	1.068	1.074	1.068	1.077
	27mm		1.063	1.069	1.075	1.069	1.078
		5/8W	1.100	1.107	1.113	1.107	1.117
	28mm		1.102	1.109	1.115	1.109	1.119
1-1/8			1.125	1.132	1.139	1.132	1.142
	29mm		1.142	1.149	1.156	1.149	1.159
	30mm		1.181	1.188	1.195	1.188	1.198
1-3/16			1.187	1.195	1.202	1.195	1.205
		11/16W	1.200	1.207	1.214	1.207	1.217
	31mm		1.220	1.227	1.234	1.227	1.237
1-1/4			1.250	1.258	1.266	1.258	1.269
	32mm		1.260	1.267	1.275	1.267	1.277
	33mm		1.299	1.306	1.314	1.306	1.316

WHITWORTH WRENCH SIZES

Unless you work with British automobiles, you won't be too concerned with this information; but if you do, it should prove quite helpful. For years the British have used a Whitworth thread on nuts, screws and bolts, thus creating the Whitworth wrench size. This screw thread form is used for the British Standard Whitworth (BSW) and the British Standard Five (BSF). There were approximately 107,000 British automobiles imported into the U.S. last year, most of them using the Whitworth System. Since the British have almost completed the changeover to the metric system, the Whitworth thread form should only be used for replacements or spare parts. The chart gives you the U.S., metric and British Whitworth wrench sizes and a comparison in decimal inches.



CONVERSION FROM FRACTIONAL INCHES TO MILLIMETERS

inch		mm	inch		mm
1/64	0.015 625	0.396 875	33/64	0.515 625	13.096 875
1/32	0.031 250	0.793 750	17/32	0.531 250	13.493 750
3/64	0.046 875	1.190 625	35/64	0.546 875	13.890 625
1/16	0.062 500	1.587 500	9/16	0.562 500	14.287 500
5/64	0.078 125	1.984 375	37/64	0.578 125	14.684 375
3/32	0.093 750	2.381 250	19/32	0.593 750	15.081 250
7/64	0.109 375	2.778 125	39/64	0.609 375	15.478 125
1/8	0.125.000	3.175 000	5/8	0.625 000	15.875 000
9/64	0.140 625	3.571 875	41/64	0.640 625	16.271 875
5/32	0.156 250	3.968 750	21/32	0.656 250	16.668 750
11/64	0.171 875	4.365 625	43/64	0.671 875	17.065 625
3/16	0.187 500	4.762 500	11/16	0.687 500	17.462 500
13/64	0.203 125	5.159 375	45/64	0.703 125	17.859 375
7/32	0.218 750	5.556 250	23/32	0.718 750	18.256 250
15/64	0.234 375	5.953 125	47/64	0.734 375	18.653 125
1/4	0.250 000	6.350 000	3/4	0.750 000	19.050 000
17/64	0.265 625	6.746 875	49/64	0.765 625	19.446 875
9/32	0.281 250	7.143 750	25/32	0.781 250	19.843 750
19/64	0.296 875	7.540 625	51/64	0.796 875	20.240 625
5/16	0.312 500	7.937 500	13/16	0.812 500	20.637 500
21/64	0.328 125	8.334 375	53/64	0.828 125	21.034 375
11/32	0.343 750	8.731 250	27/32	0.843 750	21.431 250
23/64	0.359 375	9.128 125	55/64	0.859 375	21.828 125
3/8	0.375 000	9.525 000	7/8	0.875 000	22.225 000
25/64	0.390 625	9.921 875	57/64	0.890 625	22.621 875
13/32	0.406 250	10.318 750	29/32	0.906 250	23.018 750
27/64	0.421 875	10.715 625	59/64	0.921 875	23.415 625
7/16	0.437 500	11.112 500	15/16	0.937 500	23.812 500
29/64	0.453 125	11.509 375	61/64	0.953 125	24.209 375
15/32	0.468 750	11.906 250	31/32	0.968 750	24.606 250
31/64	0.484 375	12.303 125	63/64	0.984 375	25.003 125
1/2	0.500 000	12.700 000	1	1.000 000	25.400 000

NOTE: All values in table are exact.

The chart below can be used to convert foot-pounds to meter-kilograms. The foot-pound column at the left increases in 10 ft.-lb. increments from 0 to 110 ft.-lbs. For each additional ft.-lb., read the top row of numbers. Example: If you desire 45 ft.-lbs., you would look to the number 40 in the left column and the number 5 in the top row. The conversion to meter-kilograms would be 6.22 mkgs. For your use, the conversion formula is:

FT.-LBS. X .1383 = METER-KILOGRAMS

Ft. Lbs.	0	1	2	3	4	5	6	7	8	9
	Mkgs	Mkgs	Mkgs	Mkgs	Mkgs	Mkgs	Mkgs	Mkgs	Mkgs	Mkgs
0	0	.14	.28	.42	.55	.69	.83	.97	1.11	1.25
10	1.38	1.52	1.66	1.80	1.94	2.07	2.21	2.35	2.49	2.63
20	2.77	2.90	3.04	3.18	3.32	3.46	3.60	3.73	3.87	4.01
30	4.15	4.29	4.43	4.56	4.70	4.84	4.98	5.12	5.26	5.39
40	5.53	5.67	5.81	5.95	6.09	6.22	6.36	6.50	6.64	6.78
50	6.92	7.05	7.19	7.33	7.47	7.61	7.75	7.88	8.02	8.16
60	8.30	8.44	8.57	8.71	8.85	8.90	9.13	9.27	9.40	9.54
70	9.68	9.82	9.96	10.09	10.23	10.37	10.51	10.65	10.79	10.92
80	11.01	11.20	11.34	11.48	11.62	11.75	11.89	12.03	12.17	12.31
90	12.45	12.59	12.73	12.86	13.00	13.14	13.28	13.42	13.55	13.69
100	13.83	13.97	14.11	14.25	14.38	14.52	14.66	14.80	14.94	15.08
110	15.21	15.35	15.49	15.63	15.76	15.90	16.04	16.18	16.32	16.46

CONVERSION FROM MILLIMETERS TO INCHES

mm	inch	mm	inch	mm	inch
1	0.039 370 08	36	1.417 322 8	71	2.795 275 6
2	0.078 740 16	37	1.456 692 9	72	2.834 645 7
3	0.118 110 24	38	1.496 063 0	73	2.874 015 7
4	0.157 480 31	39	1.535 433 1	74	2.913 385 8
5	0.196 850 39	40	1.574 803 1	75	2.952 755 9
6	0.236 220 47	41	1.614 173 2	76	2.992 126 0
7	0.275 590 55	42	1.653 543,3	77	3.031 496 1
8	0.314 960 63	43	1.692 913 4	78	3.070 866 1
9	0.354 330 71	44	1.732 283 5	79	3.110 236 2
10	0.393 700 8	45	1.771 653 5	80	3.149 606 3
11	0.433 070 9	46	1.811 023 6	81	3.188 976 4
12	0.472 440 9	47	1.850 393 7	82	3.228 346 5
13	0.511 811 0	48	1.889 763 8	83	3.267 716 5
14	0.551 181 1	49	1.929 133 9	84	3.307 086 6
15	0.590 551 2	50	1.968 503 9	85	3.346 456 7
16	0.629 921 3	51	2.007 874 0	86	3.385 826 8
17	0.669 291 3	52	2.047 244 1	87	3.425 196 8
18	0.708 661 4	53	2.086 614 2	88	3.464 566 9
19	0.748 031 5	54	2.125 984 2	89	3.503 937 0
20	0.787 401 6	55	2.165 354 3	90	3.543 307 1
21	0.826 771 7	56	2.204 724 4	91	3.582 677 2
22	0.866 141 7	57	2.244 094 5	92	3.622 047 2
23	0.905 511 8	58	2.283 464 6	93	3.661 417 3
24	0.944 881 9	59	2.322 834 6	94	3.700 787 4
25	0.984 252 0	60	2.362 204 7	95	3.740 157 5
26	1.023 622 0	61	2.401 574 8	96	3.779 527 6
27	1.062 992 1	62	2.440 944 9	97	3.818 897 6
28	1.102 362 2	63	2.480 315 0	98	3.858 267 7
29	1.141 732 3	64	2.519 685 0	99	3.897 637 8
30	1.181 102 4	65	2.559 055 1	100	3.937 008
31	1.220 472 4	66	2.598 425 2		
32	1.259 842 5	67	2.637 795 3		
33	1.299 212 6	68	2.677 165 4		
34	1.338 582 7	69	2.716 535 4		
35	1.377 952 8	70	2.755 905 5		

FORMULA TO CONVERT mm TO INCHES: Divide 25.4 into known mm.

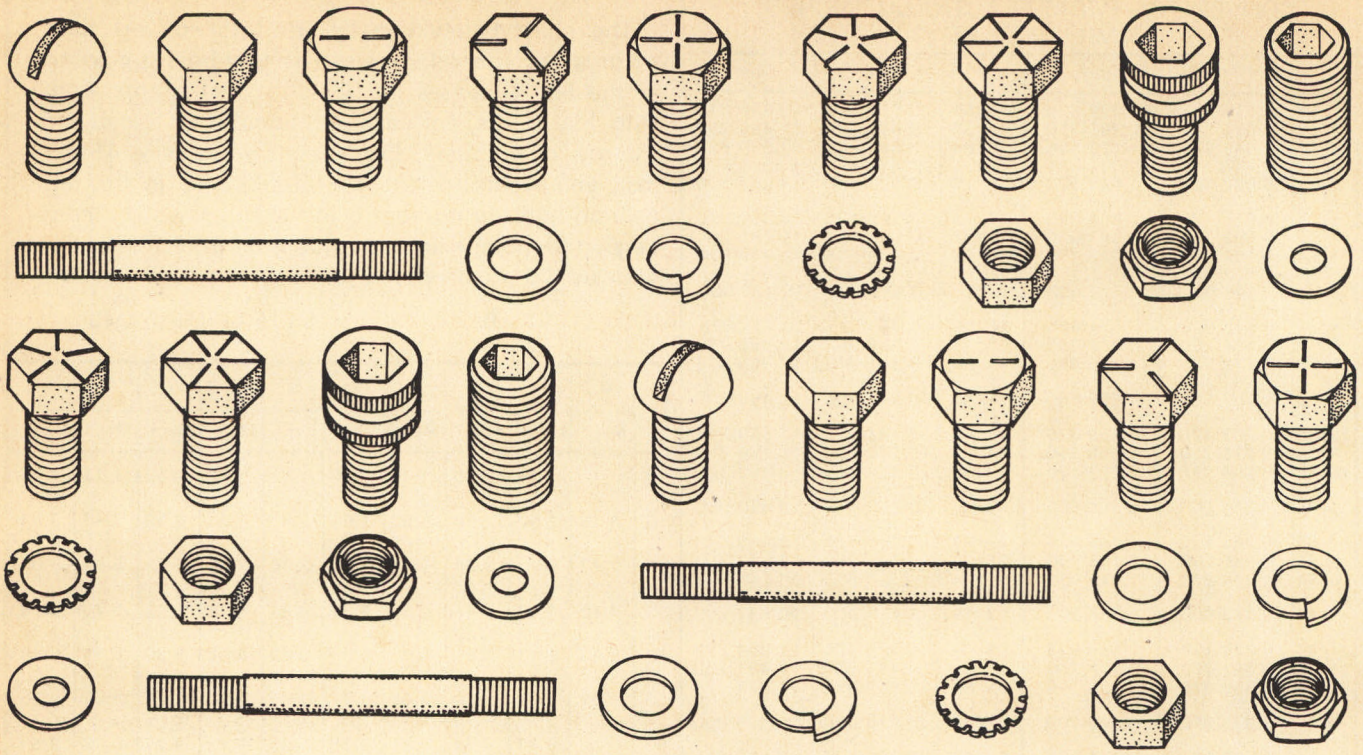
NOTE: The inch values in this table are rounded off.

CONVERSION FROM DECIMAL INCHES TO MILLIMETERS

inch	mm	inch	mm	inch	mm
1	25.4	36	914.4	71	1 803.4
2	50.8	37	939.8	72	1 828.8
3	76.2	38	965.2	73	1 854.2
4	101.6	39	990.6	74	1 879.6
5	127.0	40	1 016.0	75	1 905.0
6	152.4	41	1 041.4	76	1 930.4
7	177.8	42	1 066.8	77	1 955.8
8	203.2	43	1 092.2	78	1 981.2
9	228.6	44	1 117.6	79	2 006.6
10	254.0	45	1 143.0	80	2 032.0
11	279.4	46	1 168.4	81	2 057.4
12	304.8	47	1 193.8	82	2 082.8
13	330.2	48	1 219.2	83	2 108.2
14	355.6	49	1 244.6	84	2 133.6
15	381.0	50	1 270.0	85	2 159.0
16	406.4	51	1 295.4	86	2 184.4
17	431.8	52	1 320.8	87	2 209.8
18	457.2	53	1 346.2	88	2 235.2
19	482.6	54	1 371.6	89	2 260.6
20	508.0	55	1 397.0	90	2 286.0
21	533.4	56	1 422.4	91	2 311.4
22	558.8	57	1 447.8	92	2 336.8
23	584.2	58	1 473.2	93	2 362.2
24	609.6	59	1 498.6	94	2 387.6
25	635.0	60	1 524.0	95	2 413.0
26	660.4	61	1 549.4	96	2 438.4
27	685.8	62	1 574.8	97	2 463.8
28	711.2	63	1 600.2	98	2 489.2
29	736.6	64	1 625.6	99	2 514.6
30	762.0	65	1 651.0	100	2 540.0
31	787.4	66	1 676.4		
32	812.8	67	1 701.8		
33	838.2	68	1 727.2		
34	863.6	69	1 752.6		
35	889.0	70	1 778.0		

NOTE: All values in this table are exact.

NUTS, BOLTS AND SCREWS

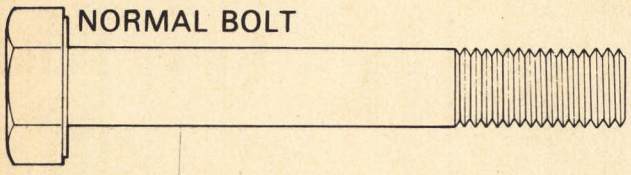


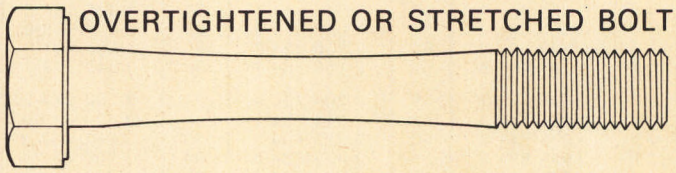
Threaded fasteners, as shown above, are the basic couplers of industry but are viewed as so commonplace that their limitations are often overlooked. Their design is created with great care and each one is made for a specific use. This is why "torque" is so important in properly tightening each of these fasteners.

A bolt used in high-stress areas of an automobile, such as the clutch, motor mount, flywheel, head areas, etc., encounters much higher stress than a bolt which holds the radiator in place.

Because the weakest link of any assembly joined together is at the *fastener,* it is important to know the ultimate strength of each fastener and the proper torque value which should be applied to it. The ultimate strength of the fastener can be determined by the diameter and the known material of the fastener. If a stronger fastener is required, you can either increase its size or use one made of a stronger material.

If a fastener is left loose and pressure is applied to the assembly, chances are the assembly will come apart even though the fastener's ultimate strength was never reached. The tighter a fastener, the more holding power it will have *provided* you do not go beyond its elastic limits. (If a fastener's elastic limits are exceeded, the fastener becomes permanently stretched, or, in other words, it's on its way to breaking.)



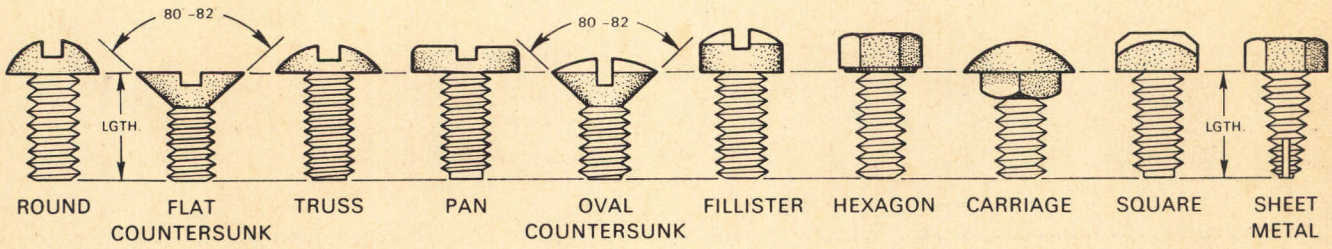


The purpose of the torque wrench is to make certain you do not exceed these elastic limits. When engineers design fasteners, they take into consideration the amount of STATIC (non-movable) load (or stress) that can be applied to the fastener, plus a VARIABLE load (sudden surge), plus a SAFETY factor of two, three or even four times the breaking point of the fastener, depending on the amount of stress the fastener might see. Remember, there are two kinds of stress: STATIC (non-movable) and DYNAMIC (movable, such as vibration). It is almost impossible to calculate the dynamic stress on a fastener so, as an educated guess, a safety factor is applied to each fastener design.

Standards for most fasteners have been established by the Society of Automotive Engineers (SAE). Special markings on the heads of bolts and cap screws indicate their tensile strength. (Tensile strength is the resistance of a material to forces of rupture and stress in the direction of length, and is expressed on all fastener charts as pounds-per-square-inch or psi.)

Fasteners with no markings on the heads are usually made of mild steel, while fasteners with numerous markings are usually made of a higher strength material (see torque chart, page 16).

The SAE number given to a fastener is a grade number which denotes its strength. Example: An SAE grade 2 fastener is made of low Carbon Steel (75,000 psi) and is much weaker than the SAE grade 8 fastener (150,000 psi), which is made of a medium Carbon Steel alloy, etc. SAE bolts of grade 0 through 2 are sufficient for most fastening jobs (see torque chart, page 16).



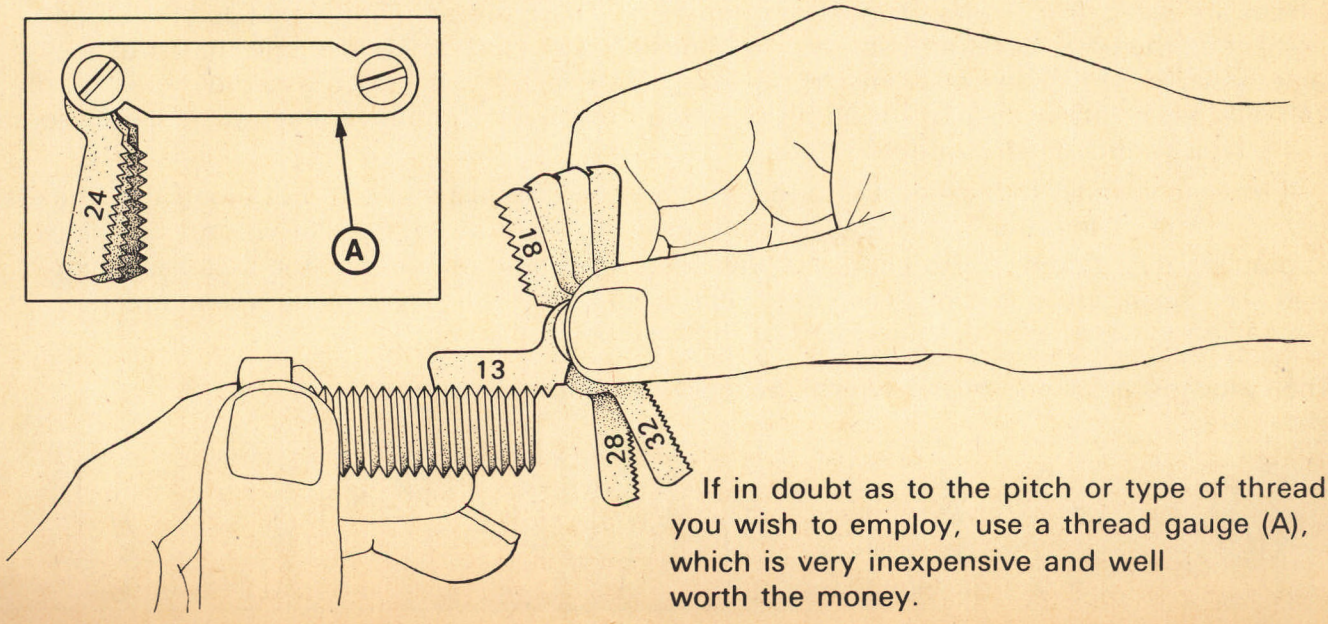
This illustration shows some of the most common types of low-grade bolts and screws in use today. Most of these have no markings shown on their heads.

CAUTION

Remember, all machine bolts and screws come in a coarse or fine thread. Be sure the threads of the bolt or screw you choose match the threads of the hole you intend to put it in. If they do not match, you will strip the threads or break the fastener.

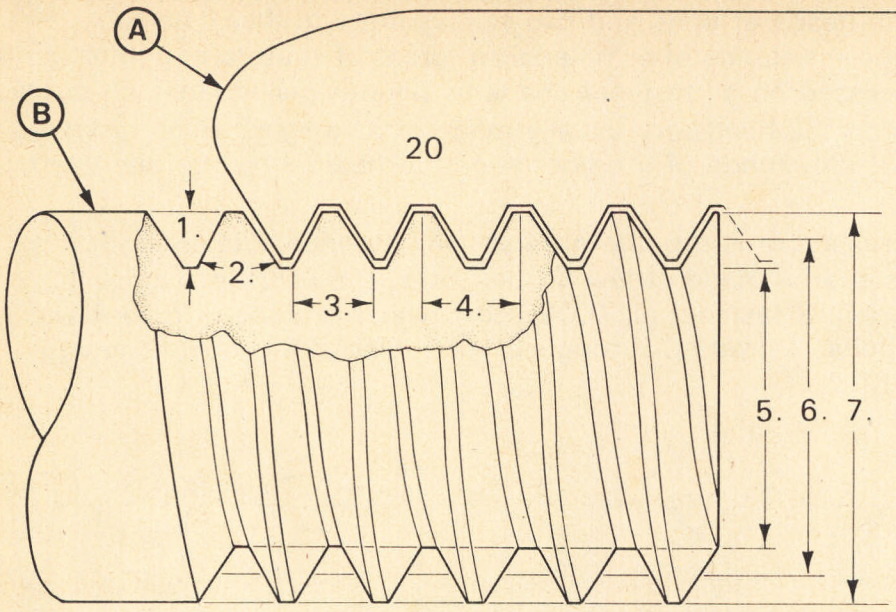
The depth of engagement of the fastener in the hole must also be considered. A good rule of thumb is to make sure the length of the fastener is 1½ times the fastener diameter. Example: If the fastener is ¼-inch in diameter, the length of the fastener should be ⅜-inch for maximum holding power (¼ times 1½ equals ¼ times 3/2 equals ⅜-inch).

A *male* fastener is the ordinary bolt or screw as you see it, and the *female* fastener is the hole in which the male fastener is inserted.



If in doubt as to the pitch or type of thread you wish to employ, use a thread gauge (A), which is very inexpensive and well worth the money.

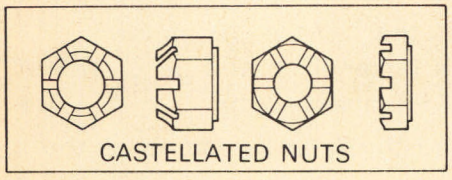
NUTS, BOLTS AND SCREWS

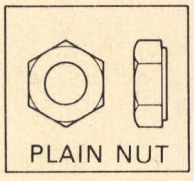


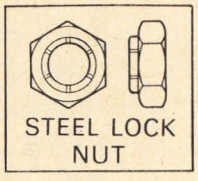
1. DEPTH
2. THREAD ANGLE
3. BASE
4. PITCH
5. MINOR DIAMETER
6. PITCH DIAMETER
7. MAJOR DIAMETER

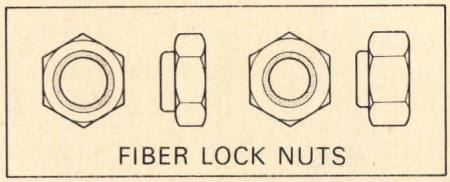
Almost every thread pitch you will ever need is available on a thread gauge. A number is stamped on each gauge blade which indicates the number of threads per inch. Example: The numbers on bolts or screws such as 4-40, 8-32, 10-32, ¼-28, ½-13, etc., indicate their size and threads per inch. The first number is the fastener diameter and the second is the number of threads per inch. To use the thread gauge (A), just match the teeth of the gauge blade with the threads of the bolt or screw (B). (The use of the thread gauge will be covered in more detail in Petersen's Third Tool Book.)

To choose the right size wrench to fit the bolt, remember that the bolthead is always 3/16-inch larger than the known diameter of the bolt. Example: If the bolt is ¼-inch in diameter and you add 3/16-inch, then the wrench size is 7/16-inch (¼ plus 3/16 equals 4/16 plus 3/16 or 7/16 inch).


CASTELLATED NUTS


PLAIN NUT

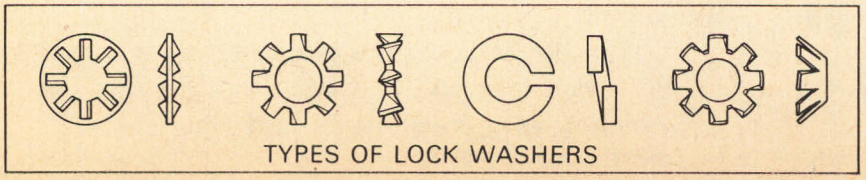

STEEL LOCK NUT

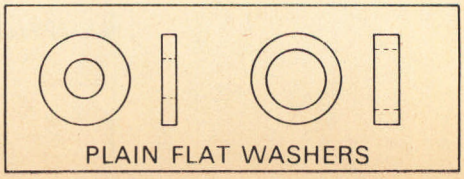

FIBER LOCK NUTS

Here are just a few words on nuts and washers. There are as many varieties of nuts and washers as there are bolts and screws. In choosing a nut, try to choose one that is of the same material as the bolt or screw being used. Materials that are alike assemble more easily with less possibility of galling (grinding or being abrasive). The above illustration shows some of the typical nuts used in industry today.

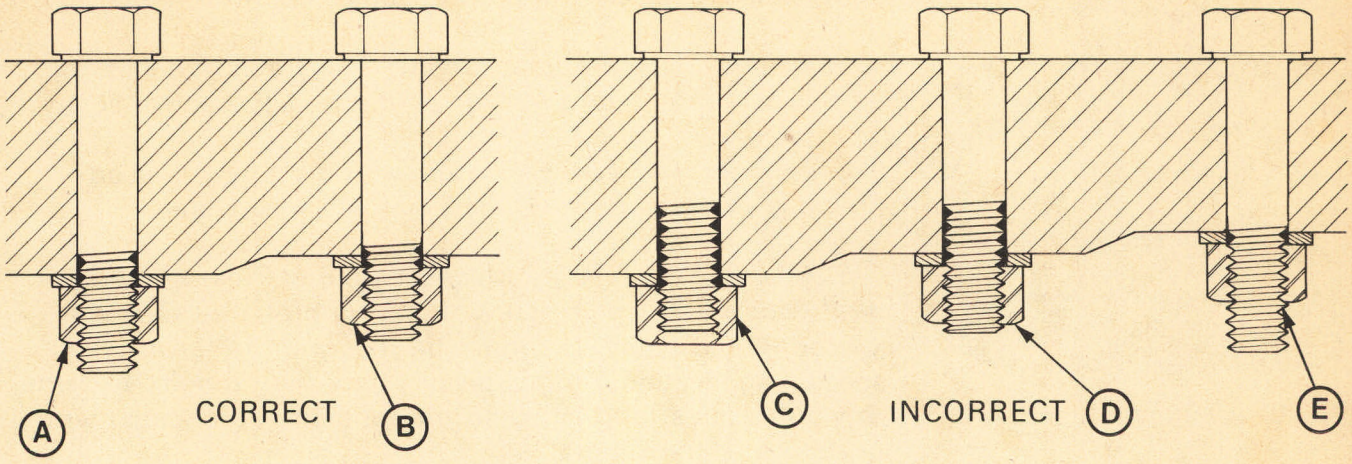
Surprisingly, most friction occurs under the head of the fastener and not along the threads; therefore, this is the area that must be controlled. The use of a hard, flat washer will help accomplish this. Again, try to choose a washer of the same material as the fastener being used. The main advantage of plain, hard, flat washers is that they provide a smooth, non-galling surface on which the head of the fastener can turn.

The following are some of the typical washers used in industry today:


TYPES OF LOCK WASHERS

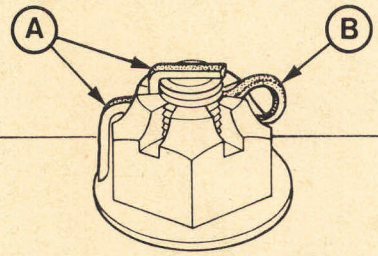

PLAIN FLAT WASHERS

The following are some correct and incorrect methods of installing bolts and nuts through an assembly and installing cotter keys through the nuts and bolts as a locking device:

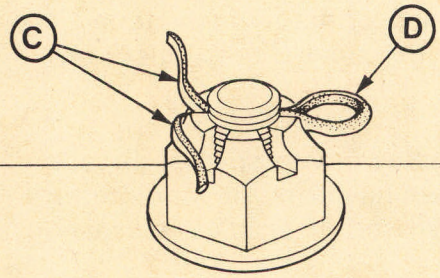


Notice that in the left CORRECT pictures (A) and (B) all the threads of the bolt are through the assembly. Only one or two threads maximum stick out beyond the end of the nut.

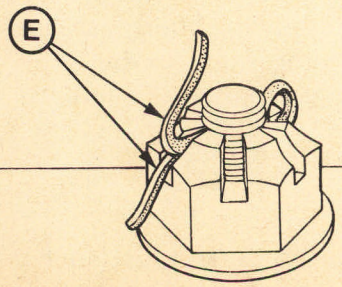
In the right INCORRECT picture (E), the bolt is too long and the nut is run down on the unthreaded portion of the bolt. In the right INCORRECT picture (D), the bolt is too short, allowing threads to be inside the assembly. Again, in the right INCORRECT picture (C), the bolt is too short, allowing threads inside the assembly and not allowing any threads to extend beyond the nut.



CORRECT — This picture shows the cotter key head (B), which is in tightly with the legs (A) bent in the proper direction. Note how one key leg (A) is bent over the bottom of the bolt.



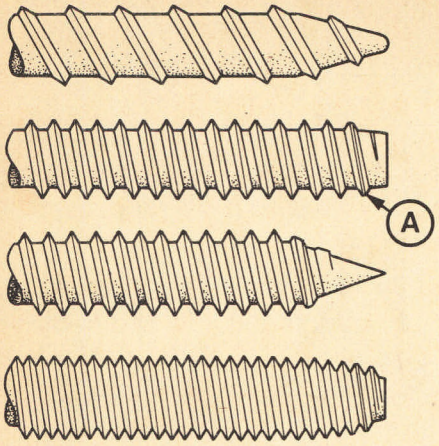
INCORRECT — In this picture, the cotter key head (D) is not placed in the proper position. Therefore, when the key legs (C) are bent, they are bent in the wrong direction.



INCORRECT — If the cotter key is not cut to the proper length prior to installation, jagged ends (E) will result, and the cotter key will have less holding power.

NUTS, BOLTS AND SCREWS

SHEET METAL, SELF-TAPPING AND METALLIC DRIVE SCREWS

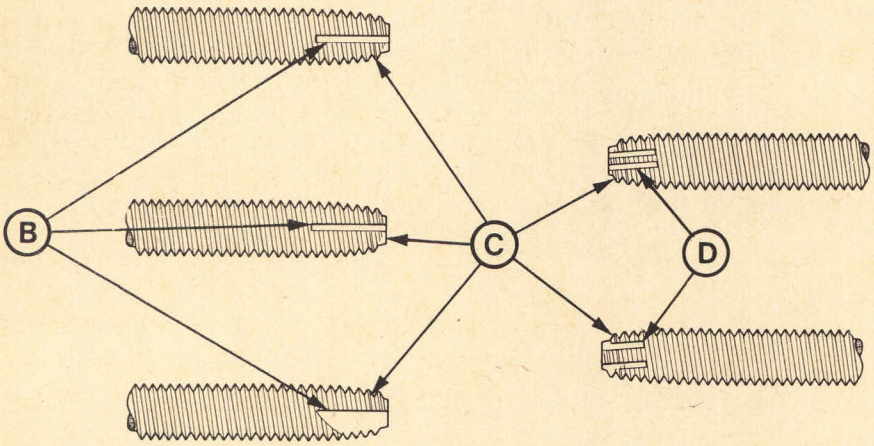


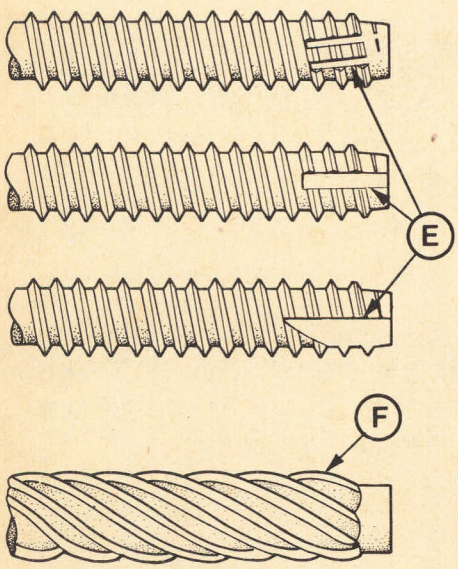
Pointed Spaced-Thread Screw: This screw is used with light sheet metal, plywood and asbestos compositions.

Blunt End Spaced-Thread Screw: The thread pitches (A) on this screw are somewhat finer than on the above screw.

Cone Point Spaced-Thread Screw: This screw is used primarily in assemblies where holes are misaligned.

Blunt End Self-Tapping Machine Screw: This screw is used where a machine screw thread is preferred over the spaced-thread types. It should be recognized that in specific applications, this type of screw may require extreme driving torques, due either to the long thread engagement or its use in hard metal.





Above are five thread-cutting screws with machine screw threads and blunt ends. They have tapered entering threads (C) and have one or more cutting edges (D) with chip cavities (B). They are used primarily in materials such as aluminum, lead die castings, steel sheets, cast iron, brass and plastic.

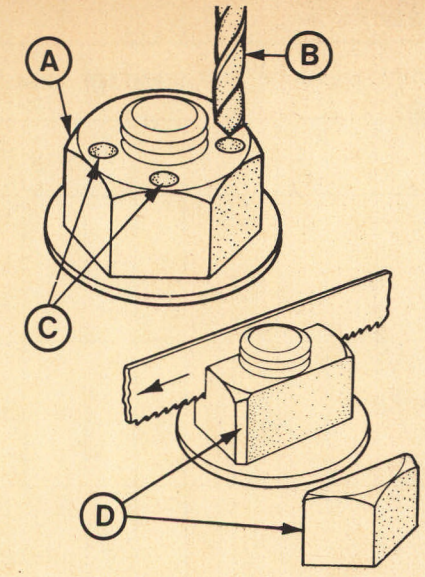
At left are thread-cutting screws with spaced threads and blunt ends. These screws have one or more cutting edges (E). They are primarily used in plastics, diecasting, fiberglass and asbestos.

This is a multiple-threaded drive screw with a large helix angle (F). Used primarily in metal, plastics, fiberglass and upholstery, this screw is forced into the material by pressure and is intended to make a permanent fastening.

HANDY HINTS

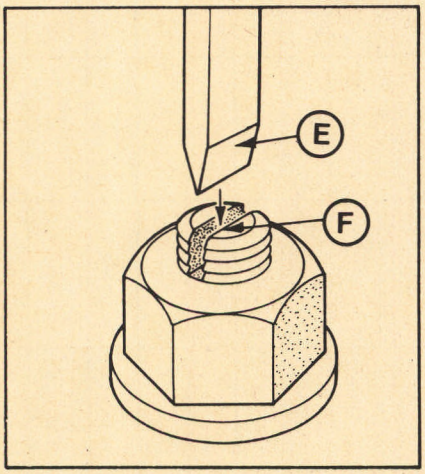
WHEN A NUT IS SEIZED

Sometimes nuts are impossible to remove. When this happens and all else fails (such as the use of penetrating oils, iodine and rapid heating of the seized nut), the nut must be destroyed. There are several methods of doing this without destroying the stud or bolt to which the nut is attached.



One method is to drill through the nut walls (A). First, using a center punch and hammer, mark the nut where you wish to drill. The hole positions should be marked so that the maximum diameter of the drill bit (B) will not break through and touch the threaded portion of the bolt or stud when drilling. The idea is to drill away as much material of the seized nut as possible, thus weakening it. Once the nut has been drilled at six points (C), the nut can be loosened with a chisel and hammer or even the proper size wrench.

The second method, which is very effective, is to use a hacksaw to cut away two of the nut walls (D). To produce maximum weakening, the saw cuts must be made as close to the bolt or stud threads as possible without damaging the threads. When the two walls of the nut have been cut away, a wrench of the proper size can be used on the remaining two walls to remove the nut.

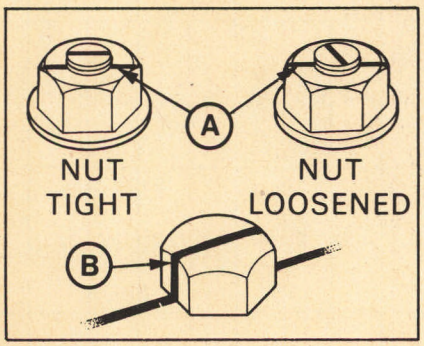


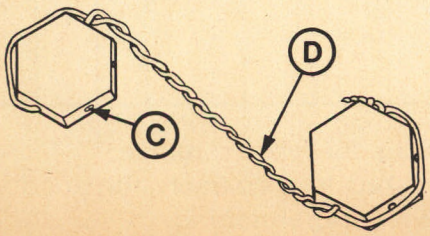
MAKING A LOCK NUT

If you're working on a car area subject to high vibration and you wish to make a lock nut from a non-locking nut, simply take a hacksaw and cut the existing screwdriver slot (F) deeper, until it's flush with the top of the nut. The slot can then be widened by carefully driving the end of a chisel (E) into the slot so that the diameter of the bolt is increased and the nut is prevented from backing off. If the slot has not been excessively widened, the nut can be loosened, using a wrench. As the nut passes over the widened slot, the slot will contract, allowing the nut to be removed. When the nut is replaced and tightened, the stud or bolt must be widened again.

WATERPROOFING BOLT THREADS

Frequently water leakage along the threads of studs or bolts will occur (engine cylinder head studs, etc.). When this happens, an effective water seal can be applied to the stud or bolt with liquid solder or paint. This treatment will tighten the bolt or stud thread as it's being screwed in, but will not prevent the nut from being run down. The surplus solder or paint in the thread will be torn off by the nut. The remainder will adhere to the thread, filling up the spaces through which liquids might otherwise leak.





LOOSE NUT INDICATOR

Nuts and bolts that are subjected to severe vibration and periodically become loose can be checked at a glance by the following methods:

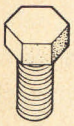
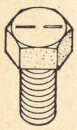
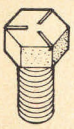
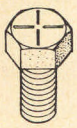
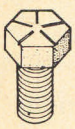
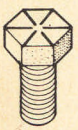
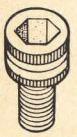
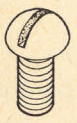
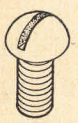
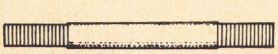
First, be sure the nut or bolt is tight and clean. Then, using fingernail polish or thick paint, place a strip of paint across the face of the stud and nut (A). If the stud or nut turns, it can be spotted at a glance.

The same method can be applied to boltheads, except that the paint strip (B) should be applied to the surface the bolt is holding as well.

If bolts and nuts loosen frequently, the nuts should be replaced with self-locking nuts and the bolts should be replaced with bolts that have a drilled hole (C) in the hex of the bolthead so that safety wire (D) can be used to secure the bolts.

NUTS, BOLTS AND SCREWS

STANDARD TORQUE VALUE CHART

FASTENER	TYPE	MINIMUM TENSILE STRENGTH	MATERIAL	BODY SIZE OR OUTSIDE DIAMETER OF FASTENER										
				2	3	4	5	6	8	10	1/4	5/16	3/8	7/
	SAE 0-1-2	74,000 PSI	LOW CARBON STEEL								6	12	20	32
	SAE 3	100,000 PSI	MEDIUM CARBON STEEL								9	17	30	47
	SAE 5	120,000 PSI	MEDIUM CARBON HEAT TREAT STEEL								10	19	33	54
	SAE 6	133,000 PSI	MED. CARBON STEEL QUENCHED TEMPERED								12.5	24	43	69
	SAE 7	133,000 PSI	MEDIUM CARBON ALLOY STEEL								13	25	44	71
	SAE 8	150,000 PSI	MEDIUM CARBON ALLOY STEEL								14	29	47	78
	SOCKET HEAD CAP SCREW	160,000 PSI	HIGH CARBON CASE HARDENED STEEL	TORQUE VALVES: All figures are foot-pounds except those marked with an asterisk (*), which are inch-pounds.							16	33	54	84
	SOCKET SET SCREW	212,000 PSI	HIGH CARBON CASE HARDENED STEEL					9*	16*	30*	70*	140*	18	29
	MACHINE SCREW YELLOW BRASS	60,000 PSI	COPPER (CU) 63% ZINC (ZU) 37%	2*	3.3*	4.4*	6.4*	8*	16*	20*	65*	110*	17	27
	SILICONE BRONZE TYPE "B"	70,000 PSI	COPPER (CU) 96% ZINC (ZNI) 2% SILICON (SI) 2%)	2.3*	3.7*	4.9*	7.2*	10*	19*	22*	70*	125*	20	30
	STUDS	Use SAE 2, 5 or 8 values when grade is known, with a nut of sufficient strength.												

There is no difference in the above chart between the torque figures for fine or coarse threads. The torque figures for a finely-threaded fastener as compared to a coarsely-threaded fastener of the same diameter may be slightly higher but hardly worth mentioning.

BODY SIZE OR OUTSIDE DIAMETER OF FASTENER																
1/2	9/16	5/8	3/4	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2	1-5/8	1-3/4	1-7/8	2	2-1/4	2-1/2	2-3/4	3
47	69	96	155	206	310	480	675	900	1100	1470	1900	2360	2750	3450	4400	7350	9500
69	103	145	234	372	551	872	1211	1624	1943	2660	3463	4695	5427	7226	8049	13450	17548
78	114	154	257	382	587	794	1105	1500	1775	2425	3150	4200	4550	6550	7175	13000	16000
106	150	209	350	550	825	1304	1815	2434	2913	3985	5189	6980	7491	10825	14983	20151	26286
110	154	215	360	570	840	1325	1825	2500	3000	4000	5300	7000	7500	11000	15500	21000	27000
119	169	230	380	600	700	1430	1975	2650	3200	4400	5650	7600	8200	12000	17000	23000	29000
125	180	250	400	640	970	1520	2130	2850	3450	4700	6100	8200	8800	13000	18000	24000	31000
43	63	100	146														
37	49	78	104	160	215	325	400		595								
41	53	88	117	180	250	365	450		655								

CAUTION

There are many varying factors which affect torque. The figures in this chart are safe figures for standard torque applications only.

TORQUE SPECIFICATIONS

The following pages contain manufacturers' recommended torque specifications. Also included are general torque specification charts for American and metric bolts. These can be used if specific manufacturers specifications are not available. However, the torque specifications recommended by manufacturers should always be used whenever possible in preference to those shown on the general chart. All specifications given are for clean and lubricated threads.

FRONT WHEEL BEARINGS

How to Use the Torque Chart

Shop manuals for late model cars recommend the use of a torque wrench to adjust front wheel bearings. The torque values indicated should be used while rotating the wheel by hand to seat the bearings. Where a re-torque is given, the spindle nut should be backed off slightly and re-torqued to the figure indicated. Then insert the cotter pin in the nearest cotter pin slot. If no re-torque figure is given, then back off the spindle nut as indicated and insert the cotter pin in the nearest cotter pin slot.

Most cars have changed to tapered roller bearings on late models; the torque values recommended for each type shown are in the chart. *All figures shown are foot-pounds unless otherwise indicated.*

FRONT WHEEL BEARING TORQUE SPECIFICATIONS

CAR MODEL	BALL BEARINGS		ROLLER BEARINGS	
	Ft. Lbs. Torque	Re-torque or back off	Ft. Lbs. Torque	Back off
BUICK (All)	25–30	12	19	1/6 turn
CADILLAC	25–30	12	30	1/4 turn
CHEVROLET	28	12	12	1/6 turn
CHRYSLER	–	–	7-1/2	1 slot
CORVAIR	–	–	12	1/6 turn
DODGE, DART	–	–	7-1/2	1 slot
FORD	–	–	17–25	1/2 turn†
LINCOLN	–	–	17–25	1/2 turn†
MERCURY	–	–	17–25	1/2 turn†
OLDSMOBILE*	17	4	30	1/2 turn
OLDSMOBILE (F-85)	10–15	1/4 turn	30	1/2 turn
PLYMOUTH	–	–	7-1/2	1 slot
PONTIAC	17	4	10–16	1/4 turn
RAMBLER, AMC	–	–	20	1/3 turn†
STUDEBAKER	–	–	15	1/6 turn
TEMPEST	17	4	10–16	1/4 turn
VALIANT	–	–	7-1/2	1 slot

*For front wheel drive models, adjust rear wheels to these specifications.
†Retighten to 12 inch-pounds.

PASSENGER CAR TORQUE SPECIFICATIONS

(Figures shown are foot-pounds)

CAR MODEL	Cylinder Heads	Connecting Rods	Main Bearings	Manifold Nuts Intake	Manifold Nuts Exhaust	Spark Plugs
BUICK						
1958-63	63-73	40-45	100-110	25-30	10-15	25-30
1961-63 Special V-8	50-55	30-35	50-55†	25-30	10-15	15-20
1962-63 Special V-6	65-70	30-35	100-110	25-30	10-15	25-30
1964 Special V-8	65-70	60-75	50-55†	25-35	10-15	25-35
1964 Special V-6		60-75	65-70	25-35	10-15	25-35
1964-65 401, 425	65-75	40-45	100-110	25-30	10-15	25-35
1965 V-6, 300	65-80	30-40	95-120	25-30	10-15	25-35
1966-67 V-6	70-75	30-40	95-120	45-55	15-20	25-35
1966 400, 401, 425	65-80	40-50	80-110	25-35	10-15	25
1966-69 300, 340, 350	65-80	30-40	95-120	45-55	15-20	25-35
1967 400, 430	100-120	45-50	80-115	45-55	15-20	15
1968-70 400, 430, 455	100	45	110	50-55	18	15
1968-71 6 cyl.	95	35	65	20-30	25	25*
1970-72 350	75	35	95	55	18	15
1971-72 455	100	45	110	65	18	15
CADILLAC						
1961	65-85	40-50	80-105	20-30	30-35	20-30
1962-63	75	45	95	25-30	60	20-30
1964-65	60	40	95	30	58	25
1966-67	60	40	90-95	25	60	25
1968-72	115	40	90	30	35	25
CHEVROLET						
1960-62 6 cyl.	90-95	33-45	100-110	25-35		25
1960-64 283, 327	60-70	30-35	60-70	25-35	**	25
1960-64 348, 409	60-70	35-45	95-105	25-35	**	25
1962-63 153, 194	90-95	30-35	45-55	15-30	**	15-25
1963-64 203	90-95	35-45	60-70	25-30	**	20-25
1964 194	90-95	35-45	60-70	**	**	20-25
1965 283, 327	60-70	30-35	60-70	25-35	18-22	25
1965 409	60-70	35-45	90-100	25-35	18-22	20-25
1965-72 153, 194, 230, 250	90-100	30-35	60-70			20-25
1966-68 283, 327, 305, 302, 307	65	35	80	30	20	25
1966-70 396, 427	80	50	95-115	30	20	25
1969-72 302, 307, 327, 350	65	45	75	30	20	25*
1971-72 Vega	60	35	65	30	30	15
1971-72 402, 454	80	50	105	30	20	15
CHRYSLER						
1961-70	70	45	85	50	30	30
1971-72 340, 360	95	45	85	40	20	30
1971-72 383, 400, 440	70	45	85	40	30	30
CORVAIR						
1961-64	10-30	20-26		None	12-27	20-25
1965-66	32-39	20-26		None	22-27	15-20
1967-69	40	25		None	25	20
DART						
1960-71 6 cyl.	65	45	85	15-17	10	30
1960-62 V-8	75	40-45	85	50	30	30
1963-69 V-8 318, 273, 340	85	40-45	85	30-40	30	30
1970 V-8 318	85	45		35	24	30
1970-72 V-8 340, 360	95	45	85	40	20	30
1972 6 cyl.	70	45	85	20	10	30

*15 for 1971-72 models

†End 65-70

**Center 25-30, End 65-70

PASSENGER CAR TORQUE SPECIFICATIONS

(Figures shown are foot-pounds)

CAR MODEL	Cylinder Heads	Connecting Rods	Main Bearings	Manifold Nuts Intake	Manifold Nuts Exhaust	Spark Plugs
DODGE						
1960-68 361, 383, 413, 426, 440	70	45	85	50	30	30
1967-69 318	85	45	85	35		30
1969-72 383, 440, 400	70	45	85	40	30	30
1970-72 340, 360, 318	95	45	85	40	20	30
1970-71 426	70	75	100		24	30
FORD, MERCURY						
1962-64 170 6 cyl., 4 cyl.	65-75	19-24	65-70	None	13-18	15-20
1962-64 223 6 cyl.	105-115	40-45	95-105	23-28	23-28	15-20
1962-64 221, 260	65-75	19-24	65-70	12-15	13-18	15-20
1962-64 292 V-8	65-75	40-45	80-90	23-28	12-18	15-20
1962-63 352, 390	80-90	40-45	95-105	32-35	12-18	15-20
1963-64 406, 427	100-110	53-58	95-105	25-28	12-18	15-20
1964 289	65-70	40-45	60-70	14-16	13-18	15-20
1965 170, 289	70-75	19-24	60-70		13-18	15-20
1965 200	70-75	19-24	95-105		13-18	15-20
1965-66 240	70-75	40-45	60-70	20-25	20-25	15-20
1965-67 427	100-110	53-58	95-105	32-35	12-18	15-20
1966-72 170, 200, 250	70-75	19-24	60-70		13-18	15-20
1966-71 352, 390, 410, 428	80-90	40-45†	95-105	32-35	18-24	15-20
1966-68 289 except Hi Perf.	65-72	18-24	60-70	20-22	15-20	15-20
1966-68 289 Hi Perf.	65-72	40-45	60-70	20-22	15-20	15-20
1967-72 240	70-75	40-45	60-70	23-28	23-28	15-20
1969-72 302-2V	65-72	19-24	60-70	23-25	12-16	15-20
1970-71 351-W	95-100	40-45	95-105	23-25	18-24	15-20
1971-72 Pinto 98	65-70	30-35	65-70	12-15	9-12	22-28
1971-72 Pinto 122	65-80	29-34	65-75	12-15	12-15	14-20
1972 351, 400	95-105	40-45	95-105*	21-25	12-16	15-20
1972 429	130-140	40-45	95-105	25-30	28-33	15-20
LINCOLN						
1961-62	95-105	40-45	95-105	18-21	15-21	15-20
1963	95-105	40-45	95-105	25-28	15-21	15-20
1964-65	125-135	40-45	95-105	25	15-21	15-20
1966-67	135-145	40-45	95-105	20-25	15-21	15-20
1968	130-140	40-45	95-105	25-30	15-21	15-20
1969-72	130-140	40-45	95-105	25-30	28-33	15-20
OLDSMOBILE						
1962-64 88, 98	60-80	32-42	90-120**	22-34	19-25	18-34
1962-63 F-85	45-55	30-35	65-70	25-30	18-24	12-17
1964 V-6	65-70	30-35	65-70	25-35	25-35	25-35
1964-65 V-6	65-70	30-35	65-70	25-35	25-35	25-35
1965 V-8	80	42	80**	35	25	35
1966-71 6 cyl.	95	35	65	25	25	25
1966-72 330, 350	80-85	42	80**	35	25	35
1966-72 400, 425, 455	80-85	42	120	35	25	35

†55 on 428 engine

**40 more on rear bolt

*35-45 for ⅜" bolt

PASSENGER CAR TORQUE SPECIFICATIONS

(Figures shown are foot-pounds)

CAR MODEL	Cylinder Heads	Connecting Rods	Main Bearings	Manifold Nuts Intake	Manifold Nuts Exhaust	Spark Plugs
PLYMOUTH						
1960-71 6 cyl.	65-70	45-50	80-85	15	10	30
1960-68 V-8 361, 383, 314, 426	70	45	85	50	30	30
1963-69 V-8 318, 273, 340	85	45	85	30-40		30
1967-68 V-8 383, 440	70	45	85	50	30	30
1969-71 V-8 383, 440	70	45	85	40	30	30
1970 V-8 318	85	45	85	35	24	30
1970-71 V-8 340	95	45	85	35	20	30
1971 V-8 318, 360	95	45	85	35	24	30
1970-71 426	70	75	100		24	30
1972 6 cyl.	70	45	85	20	10	30
1972 318, 340, 360	95	45	85	40	20	30
1972 400, 440	70	45	85	40	30	30
PONTIAC						
1960-62	95	45	95†	30-40	25-30	25
1963-66	85-100	40-46	90-110†	30-45	20-35	25
1967-72 V-8 (exc. 307)	95	43	100†	40	30	15
1971-72 6 cyl.	95	35	65	25	25	15
1972 307	65	45	75	30	20	15
RAMBLER, A.M.C.						
1960-61 6 cyl.	60-65	27-30	60-70	End 10, Center 25		30
1960-65 V-8	60-65	46-50	85, Rear 55	20-25		30
1961-64 6 cyl. alum.	50-53	27-30	55-58	End 10, Center 25		25
1962-65 6 cyl. L-Head	58-62	27-30	66-70		20-25	25-30
1962-65 6 cyl. OHV 195.6	58-62	27-30	66-70	End 10, Center 25		25-30
1965 6 cyl. 232	80-85	27-30	75-85	20-25		25-30
1966-72 6 cyl.	80-85	27-30	75-85	20-25	20-25	25-30
1966 V-8	58-62	46-50	85, Rear 55	20-30	30-35	25-30
1967 V-8	72-77	27-30	95-105	40-45	30-35	25-30
1968-70 V-8 390	90-100	26-30	95-105	40-45	30-35	25-30
1971-72 V-8, 304, 360	105-115	26-30	95-105	40-45	30-35	25-30
1971-72 V-8, 401	105-115	35-40	95-105	40-45	30-35	25-30
STUDEBAKER						
1960-64 6 cyl.	46-50	28-32	88-93	26-30		25-30
1960-64 V-8	55-65	52-54	85-95	26-30		25-30
1965-66 6 cyl.	90-100	30-35	60-70	25-35	25	25-30
1965-66 V-8	60-70	30-35	60-70	25-35	20	25-30
TEMPEST						
1961-63 4 cyl.	85-100	40-46	90-110†	30-45	20-35	15-25
1961-62 V-8	50-55	30-35	65-70	25-30	10-15	15-20
1963-64 V-8	85-100	40-46	90-110†	30-45	20-35	15-25
1964-65 6 cyl.	85-100	30-35	60-70	25-40	20-35	15-25
1965-70 V-8	90-100	40-46	90-110†	35-45	25-35	15-25
1966 6 cyl.	86-100	31-35	90-110	21-35	21-35	15-25
1967-70 6 cyl.	95	33	100	30	30	20
1971-72 See Pontiac						
VALIANT, LANCER						
1960-70 6 cyl.	65	45	85††	15	10	30
1965-69 V-8	85	45	85	30-40	30	30
1970 V-8 318	85	45	85	35	24	30
1971-72 See Plymouth						

†Rear Main 120

††50 for aluminum engine

TRUCK ENGINE TORQUE SPECIFICATIONS

(Figures shown are foot-pounds)

MAKE AND MODEL	Cylinder Heads	Connecting Rods	Main Bearings	Spark Plugs
CATERPILLAR				
1140, 1145, 1150, 1160	95	65	175	
1670	165-175	85	155	
1673-B	155-165	85	155	
1673-C	170-180	30††	175	
1674	185	20††	220	
1676	180	50††	350	
1693	300	20††	350	
CHEVROLET				
4-153, 6-194	90	30	65	25
6-230	90	40	65	25
6-235, 261	90	40	105	25
6-250, 292	95	40	65	25†††
8-265	65	30	65	25
8-283, 327	65	35	80	25
8-322	65	40	105	25
8-348, 409	65	40	100	25
8-366	80	50	115	25
8-396, 427	80	50	115	25†††
V-6 401, 478	68	68	Rear 90 Others 140	25†††
307, 350	65	45	70	25
1971-72 350	65	35	70	15
1971-72 366, 427	80	55	100	15
CUMMINS				
J (2 valve 11/16 capscrew)	240-260	30*	45-50*	
J anc C (4 valve)	390-400	30*	45-50*	
H and NH (4⅞″-5⅛″)	460-480	50-55*	140-145**	
NH (5½″)	280-300	50-55*	140-145**	
V-12 (5⅛″)	440-460	140	120-125*	
V-12 (5½″)	315-335	140	120-125*	
V6-200, V8-265	175-185	60-65*	170-180*	
V-903	280-300	60-65*	170-180*	
V8-350, VT8-430	175-180	75-80*	170-180*	
V6-140, V8-185	100-105	20-25*	175-185	
L	550 ***	95-105*	100-105*	
DODGE				
6-170, 225, 251	65	45	85	30
6-230, 265	70	45	85	30
8-259, 270, 273, 315, 318, 331, 354	85	45	85	30
8-361, 383, 413	70	45	85	30
6-413	65	75	85	30
6-198	65	45	85	30
V-8 318, 360	95	45	85	30†
V-8 400, 361, 413	70	45	85	30

*Plus 60° turn
†20 for 18 MM

**Plus 30° turn
††Plus 90° turn

***650 on push-tube side.
†††15 for tapered seat

TRUCK ENGINE TORQUE SPECIFICATIONS

(Figures shown are foot-pounds)

MAKE AND MODEL	Cylinder Heads	Connecting Rods	Main Bearings	Spark Plugs
FORD				
1960-63 8-401, 477, 543	130-150	60-65	150-164	15-20
1961-66 6-144, 170	70-75	60-70	75-85	15-20
1961-64 8-292	70-75	40-45	80-90	15-20
1962-64 6-223, 262	105-115	40-45	90-105	15-20
1962-63 8-302, 332	105-115	40-45	120-130	15-20
1964-65 8-401, 477, 534	170-180	60-65	150-165	15-20
1964-69 8-330, 361, 391	80-90	40-45	95-105	15-20
1965-72 6-240, 300	70-75	40-45	60-70	15-20
1966-69 8-401, 477, 534	170-180	60-65	130-150	15-20
1967-72 170	70-75	19-24	60-70	15-20
1968-72 302	65-72	19-24	60-70	15-20
G.M.C.				
4-153, 6-194	90-95	30-35	60-70	20-25
6-230, 6-292	90-95	35-45	60-70	20-25
6-248, 6-270	90-100	40-45	90-100	20-25
8-288, 8-316, 8-347	90-95	45	Rear 140 Others 100	15-20
6-302	90-100	40-45	90-100	15-20
V-6 305, 351, 401, 478, V-12 702	65-72	65-75	Rear 90 Others 140	22-27
8-324, 370	65-70	40-50	Rear 120 Others 95	25
8-336	90-95	45	Rear 140 Others 100	23-27
6-360	80-90	65-75	90-100	15-20
6-426	80-90	80	90-100	23-27
6-503	75-80	80	90-100	23-27
8-637	130-135	55-65	170-180	23-27
INTERNATIONAL				
4-152	75-80	40-45	75-80	28-30
A-55	45	35	77-80	28-30
BD-220, 240, BG-220, 241, BD-264, 265	85-95	45-55	75-85	28-30
BD-269, 282, 308, RD Series	100-110	70	100-110	28-30
SD-220, 240	85-95	45-55	75-85	28-30
V-266, 304, 345	90-100	45-55	75-85	28-30
V-401, 461, 478, V-549	80-90	60-70	100-110	28-30
JEEP				
L-Head 4	60 70	7/16" bolt 55 3/8" bolt 40	65-75	25-30
F-Head 4	60-70	35-45	65-75	25-30
L-Head 6	30-35	40-45	85-95	25-30
6-230	90-95	40-45	85-95	20-30
6-232	80-85	46-50	75-85	25-30
V8-327	58-62	27-30	Rear 55 Others 85	25-30

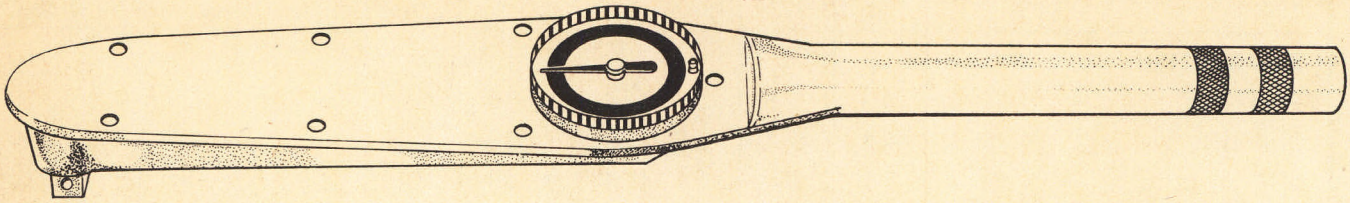
FOREIGN CAR TORQUE SPECIFICATIONS

MAKE AND MODEL	Cylinder Heads		Connecting Rods		Main Bearings		Manifold Nuts		Spark Plugs	
	Ft.-Lbs.	Mkgs.	Ft.-Lbs.	Mkgs.	Ft.-Lbs.	Mkgs.	Ft.-Lbs.	Mkgs.	Ft.-Lbs.	Mkgs.
AUSTIN-HEALEY										
Sprite MK IV	50	6.9	40	5.5	60	8.3	15	2.1	15	4.2
COLT										
All	52	7.3	46	6.4	38	5.3	13	1.8	18	2.5
CRICKET										
All	56	7.8	29	4.0	55	7.6	16	2.2	12	1.7
DATSUN										
1000LB-10	42	5.8	25	3.4	37	5.1	18	2.5	28	3.9
1300, 1600	40	5.5	22	3.0	36	5.0	20	2.8	13	1.8
1800	62	8.6	36	5.0	76	10.5	22	3.0	26	3.6
2000 PL-130	48	6.6	40	5.5	78	10.8	24	3.3	30	4.1
2000 SRL-311	65	9.0	65	9.0	65	9.0	22	3.0	13	1.8
2300	42	5.8	22	3.0	55	7.6	22	3.0	13	1.8
FIAT										
500F, L	24	3.3	25	3.5	15	2.1	18	2.5	20	2.8
600D, 850 Super, Special	28	3.9	25	3.5	45	6.2	14	1.9	20	2.8
850 Coupe, Spider	36	5.0	29	4.0	44	6.1	14	1.9	20	2.8
1100	58	8.0	25	3.5	45	6.2	14	1.9	20	2.8
128	69	9.5	37	5.1	62	8.6	20	2.8	28	3.9
124, 125	56	7.7	37	5.1	60	8.3	18	2.5	30	4.1
130	80	11.1	55	7.6	80	11.1	18	2.5	28	3.9
Dino Spider, Coupe	55	7.6	58	8.0	72	10.0	14	1.9	22	3.0
1600	58	8	40	5.5	58	8	18	2.5	29	4
FORD (English)										
Escort 1100, 1300, Capri 1300	68	9.4	33	4.6	68	9.4	17	2.3	26	3.6
Escort Twin Cam	63	8.7	45	6.2	58	8.0			26	3.6
Cortina 1300, 1600, Capri 1600	68	9.4	23	3.2	58	8.0	17	2.3	26	3.6
Cortina Lotus	63	8.7	45	6.2	58	8.0			26	3.6
Corsair, Zephyr, Zodiac	68	9.4	23	3.2	58	8.0	15	2.1	26	3.6
JAGUAR										
XJ-6	54	7.5	37	5.1	125	17.3				
240, 420G, E, S2	54	7.5	37	5.1	83	11.5				
MERCEDES-BENZ										
200, 220	65	9.0	40	5.5	65	9.0			25	3.5
230, 250 Models	65	9.0	45	6.2	58	8.0			25	3.5
280S, SE, SL, 300 SEL	72	10.0	44	6.1	58	8.0			25	3.5
600	58	8.0	36	5.0	60	8.3			25	3.5
MG										
Midget MK III	50	6.9	40	5.5	60	8.3	15	2.1	30	4.1
1300 MK II	40	5.5	35	4.8	60	8.3	15	2.1	30	4.1
MGB	44	6.1	40	5.5	70	9.7	25	3.5	30	4.1
MGC	75	10.4	50	6.9	75	10.4	15	2.1	30	4.1
OPEL										
Kadett, GT-1SR	33	4.6	20	2.8	47	6.5				
Olympia, Rekord 7S, 9S	65	9.0	36	5.0	80	11.1				
Rekord Sprint, 6 cyl.	72	10.0	36	5.0	80	11.1				
GT-1, 9S	58	8.0	36	5.0	72	10.0				
Commodore, Kapitan, Admiral	72	10.0	36	5.0	72	10.0				
Diplomat	65	9.0	44	6.1	72	10.0				

FOREIGN CAR TORQUE SPECIFICATIONS

MAKE AND MODEL	Cylinder Heads		Connecting Rods		Main Bearings		Manifold Nuts		Spark Plugs	
	Ft.-Lbs.	Mkgs.	Ft.-Lbs.	Mkgs.	Ft.-Lbs.	Mkgs.	Ft.-Lbs.	Mkgs.	Ft.-Lbs.	Mkgs.
PEUGEOT										
204, B, C	40	5.5	29	4.0	38	5.3			20	2.8
204 BD	44	6.1	27	3.7	38	5.3			35	4.8
404 U, L	51	7.0	31	4.3	54	7.5			18	2.5
404 LD, U6D	52	7.2	45	6.2	75	10.4	15	2.1	35	4.8
504	50	6.9	29	4.0	54	7.5			16	2.2
PORSCHE										
912	22	3.0	33	4.6	29	4.0			18	2.5
911T, E, S	23	3.2	36	5.0	25	3.5			18	2.5
911R, 906, 910	24	3.3	44	6.1	58	8.0				
RENAULT										
R-4, R-1120	47	6.5	25	3.5	44	6.1			13	1.8
R-6, R-8, R1132, 8S	44	6.1	25	3.5	44	6.1			13	1.8
Gordini 1300	54	7.5	33	4.6	47	6.5			13	1.8
10 Luxe, Super, R1190	44	6.1	25	3.5	44	6.1			13	1.8
16 Luxe, 16TA	52	7.2	33	4.6	47	6.5			22	3.0
16TS	60	8.3	33	4.6	47	6.5			22	3.0
R-1150, R-1152, R-1153	53	7.3	30	4.5	45	6.5	15	2.0		
R-1151	58	8.0	30	4.5	45	6.5	22	3.0		
R-1172, R-1331	58	8.0	30	4.5	45	6.5	15	2.0		
SAAB										
95, 96, Monte Carlo	68	9.5	25	3.5	72	1.0	15	2.1	25	3.5
99	54	7.5	40	5.5	58	8.0	18	2.5	15	2.0
SIMCA										
1000 Series	47	6.5	17	2.3	47	6.5	13	1.8	20	2.8
1200 S	45	6.2	31	4.3	47	6.5	9	1.2	22	3.0
1301 LS, GL	47	6.5	22	3.0	40	5.5	14	1.9	21	2.9
1501 Series	58	8.0	33	4.6	47	6.5	14	1.9	21	2.9
TOYOTA										
Corolla 1100	45	6.2	33	4.6	45	6.2	18	2.5	13	1.8
Corona 1600, 1900	80	11.1	44	6.1	76	10.5	22	3.0	14	1.9
2000 GT, Crown 2300			33	4.6	72	10.0	25	3.5	13	1.8
TRIUMPH										
Herald 1200, 1300	44	6.1	40	5.5	53	7.3	25	3.5	15	2.1
1300 TC, Spitfire MK III	44	6.1	40	5.5	53	7.3			15	2.1
TR-6, GT-6, Vittesse MK II	68	9.4	40	5.5	58	8.0	25	3.5	15	2.1
2000	44	6.1	40	5.5	58	8.0	21	2.9	15	2.1
VOLKSWAGEN							Int. 5	.7		
All	23	3.2	24	3.3			Exh. 14	1.9	25	3.5
VOLVO										
All	65	9.0	40	5.5	90	12.4			30	4.1

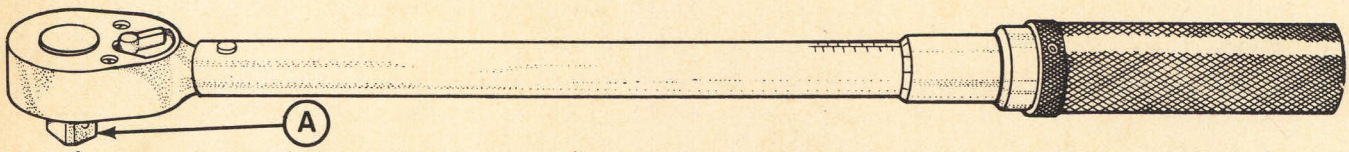
TORQUE WRENCHES



Torque is basically the amount of twisting action at a given point. Without some way of measuring torque, it is impossible for any mechanic to tighten a series of bolts, nuts or screws to an exact, predetermined tension. This is where torque wrenches come in.

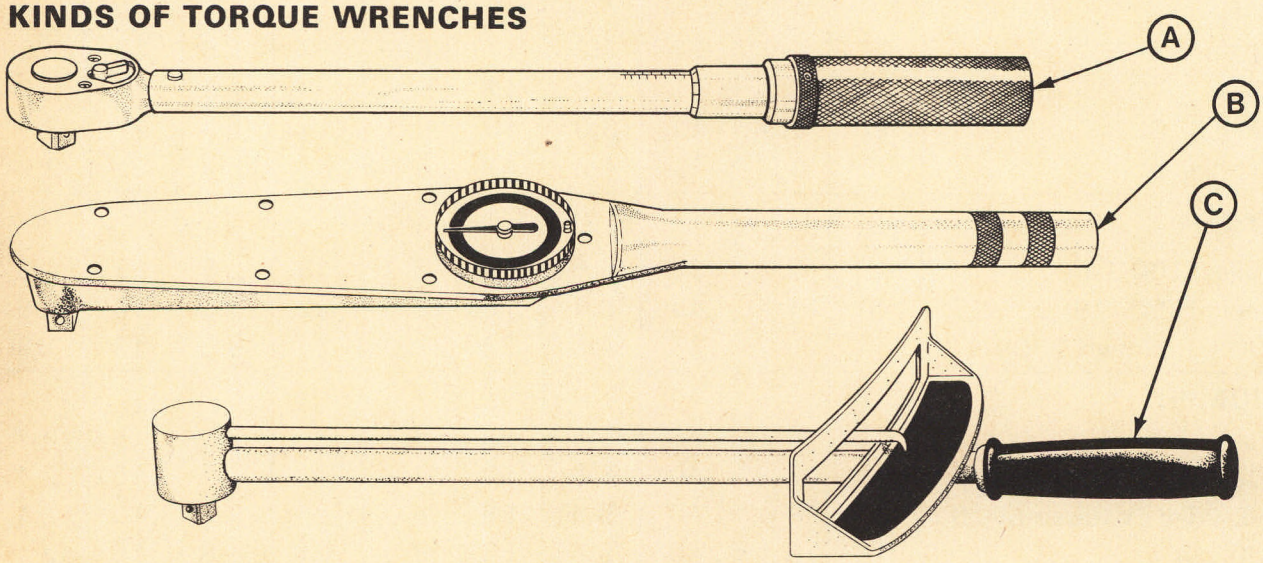
With today's modern machinery, which uses many new and different kinds of light alloys (an alloy being a mixture of two or more metals), torqueing of bolts, nuts and screws becomes a very critical operation. Applying too little torque will cause leaks (liquid or gas). Applying too much torque will cause leaks too, but will also cause distortion and major damage to expensive parts.

There are many different kinds of torque wrenches on the market today, but for reliability, always purchase a brand name torque wrench, one made by a company that will stand behind the quality and workmanship of their product.



A torque wrench is similar in operation to the ratchet handle of a socket wrench. It is made with a strong spring connection between the handle and the socket attachment or square drive (A). Torque wrenches can be purchased with square drives from ¼-inch up to 1 inch in size—and even larger for heavy industrial use.

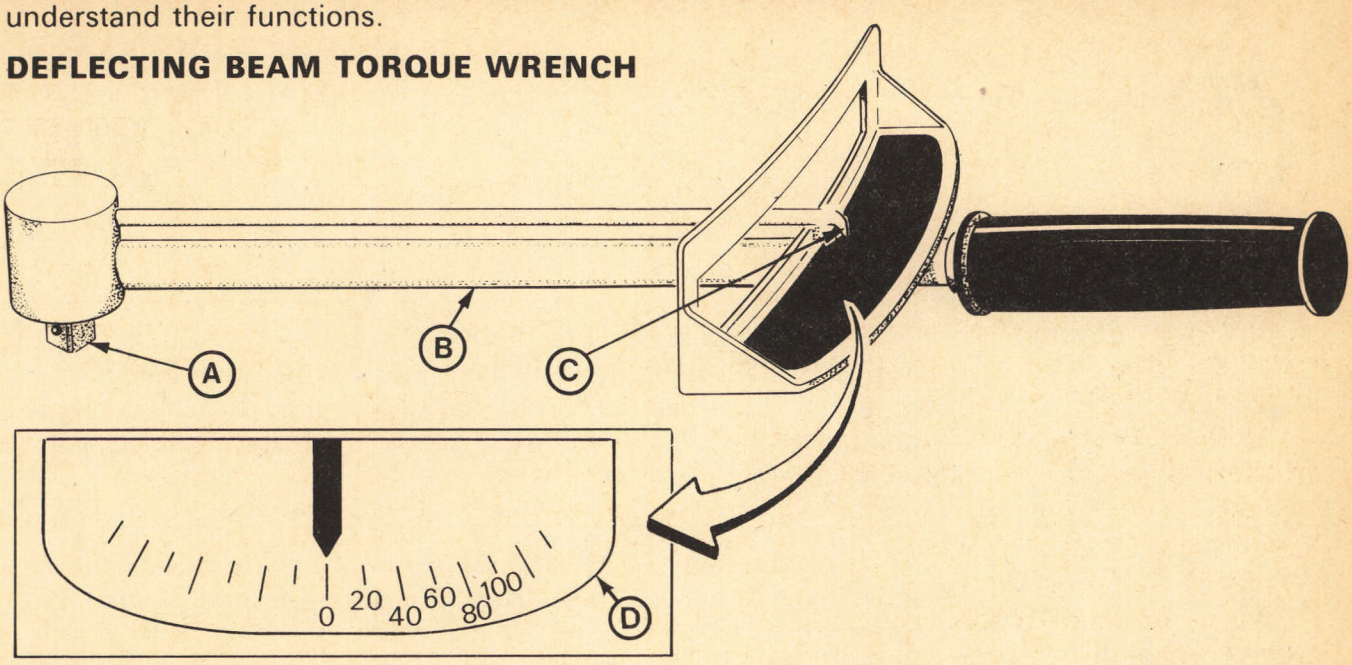
KINDS OF TORQUE WRENCHES



Choosing the kind of torque wrench to use for a particular application is in many cases a matter of personal preference. The dial indicating type (B) and the audible click type of torque wrenches (A) are preferable to the deflecting beam type of torque wrench (C). The audible click torque wrench is preferred above all, since it can be used in places of limited accessibility where it would be difficult to read a dial or scale while performing the tightening sequence.

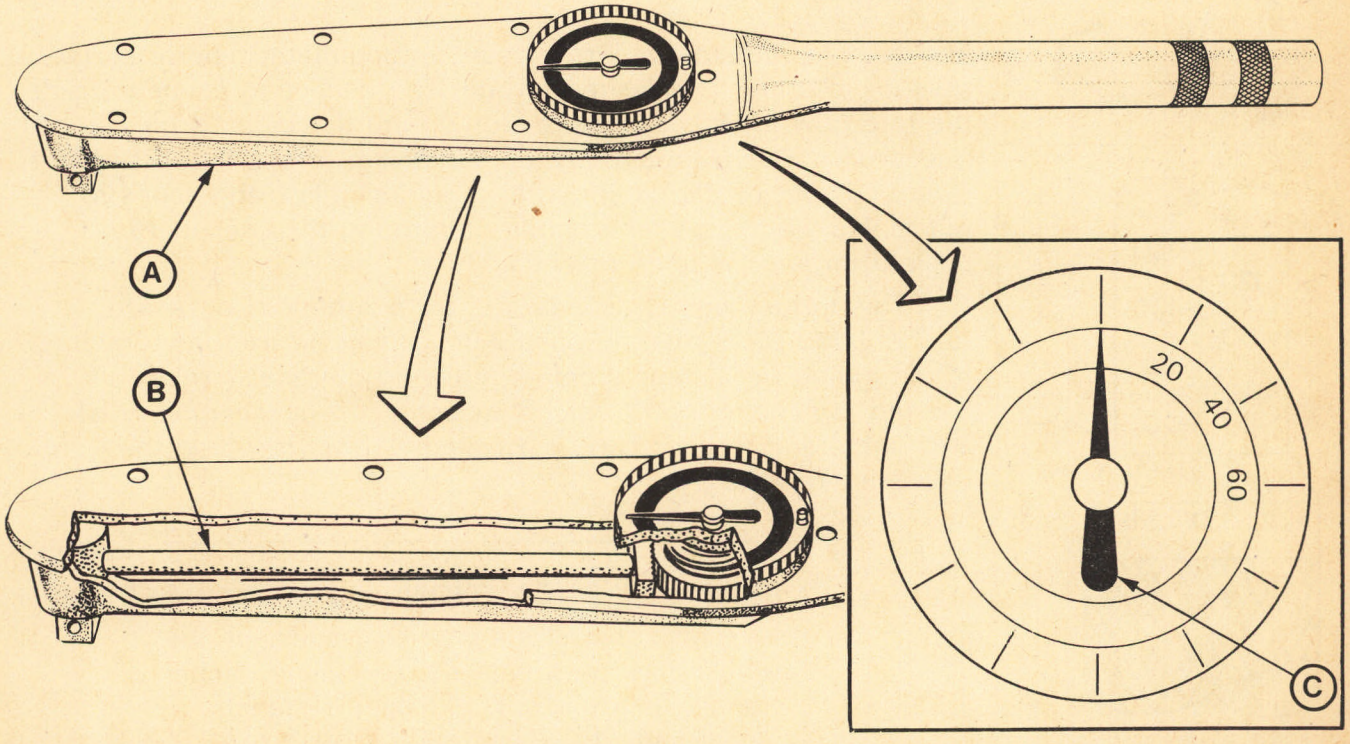
Now let's talk about the operation of these three torque wrenches so that you will understand their functions.

DEFLECTING BEAM TORQUE WRENCH



The deflecting beam is the lever (B) attached to the handle of the deflecting beam type of torque wrench. In use, the lever deflects (bends) when a load is applied to the handle. A pointer (C) attached to the square drive (A) remains straight when the beam deflects and shows the applied load as torque on an indicator plate (D) attached to the torque wrench.

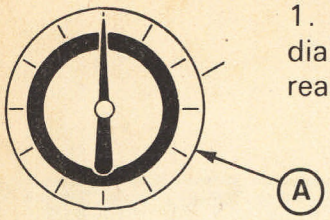
DIAL INDICATOR TORQUE WRENCH



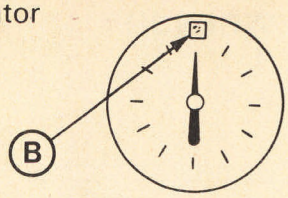
The dial indicator type of torque wrench operates exactly like the deflecting beam type except that it is encased in a rigid frame (A). The deflecting element (B) inside the rigid frame is attached in such a way as to actuate a pointer (C) in the indicator dial, which shows the applied load as torque.

TORQUE WRENCHES

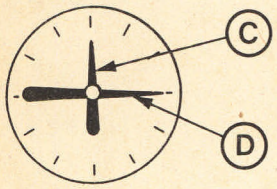
Some desirable features to look for on better-quality dial indicator torque wrenches are:



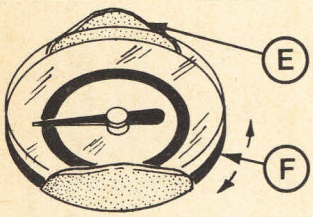
1. Oversized indicator dials (A) for easier reading.



2. Light signal feature: Set the dial at zero torque. When the desired torque is reached, the light (B) goes on—great for working in dark areas.



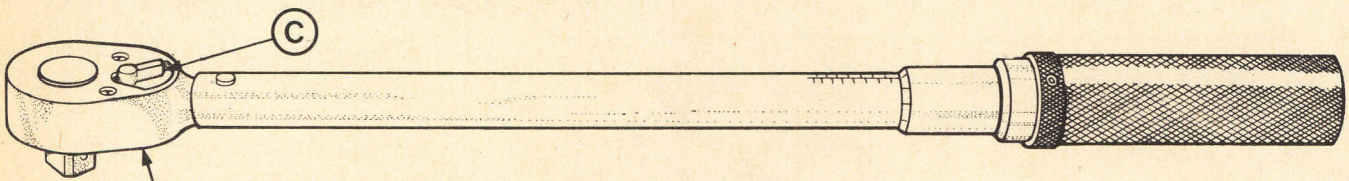
3. Follow-up pointers: Set the dial at zero torque (C). As the torque load is being applied, two indicator pointers follow the scale up to the desired torque. When the load is released, one pointer (D) remains at the exact point of release. This lets you verify torque accurately.

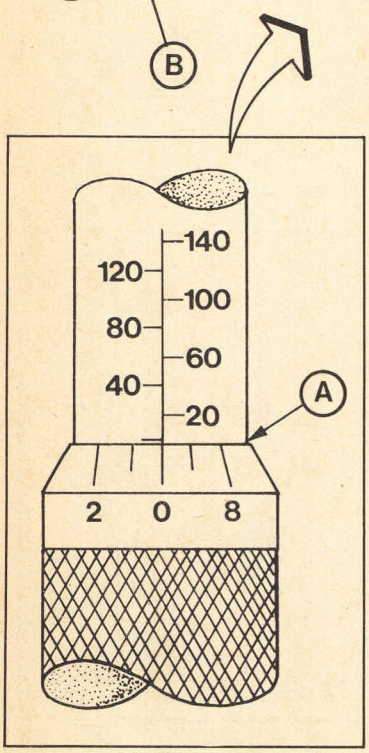


4. Protective guards: Guards (E) are built on the side of the indicator dial face for protection in case the torque wrench is dropped.

5. Dial movable in both directions (F): This feature allows you to torque right- or left-hand-threaded fasteners.

AUDIBLE CLICK TORQUE WRENCH





The audible click torque wrench has a micrometer type of barrel (A) for presetting the desired torque. The deflecting element inside the torque wrench is a compression spring that applies pressure to a lever in a detent (notch). When the preset torque is reached, the lever slips out of the detent with an audible click and sends a noticeable vibration to the handle, informing the user that his desired torque has been reached.

This torque wrench is excellent for a variety of uses. The ratchet head (B) is dual-purpose. First, it can be used as a ratchet for snugging up fasteners before applying the final torque. Second, by changing the ratchet selector (C), fasteners with left- and right-hand threads can be torqued without resetting the micrometer barrel (A).

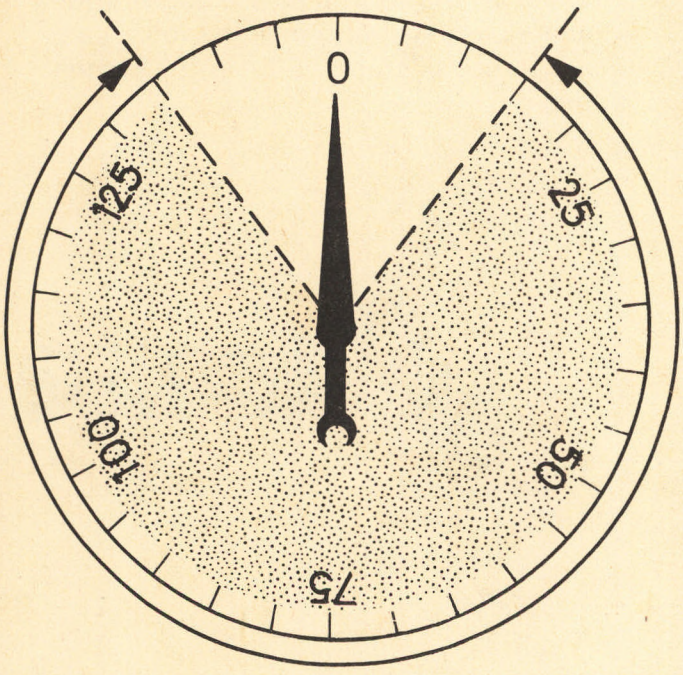
CAUTION

Never use *any* torque wrench, especially the audible click ones with the reversible ratchet head, as just a tool to loosen fasteners. Permanent damage can be done to your precision instrument.

Now let's get into the actual use of your torque wrench.

HOW TO CHOOSE THE CORRECT TORQUE WRENCH

Basically, all torque wrenches perform the same function, that of torqueing fasteners. The only difference is the manner in which you select the desired torque for your particular type of torque wrench.



ACCURATE TORQUE RANGE

When selecting a torque wrench for a particular application, the range of the wrench must be considered. Some of the better brand-name torque wrench companies guarantee the precision of their torque wrenches to no more than a 1% or 2% degree of error through the full range of their scale (i.e. 0-150 inch-pounds). But on an average torque wrench, the required torque value should fall in the middle 80% of the total torque wrench range. Example: On a torque wrench scale of 0-150 inch-pounds, the accurate torque range is from 15-135 inch-pounds. No lower and no higher. If you must go lower or higher, select another torque wrench with a different range. The accuracy of most torque wrenches tends to decrease at the extreme ends of their torque range. The greatest accuracy is obtained in the range above 10% and below 90%. Most repair manuals give specific torque values for specific fasteners on that product. By taking a quick glance through the repair manual, you can determine your torque wrench needs.

DIVIDE	BY	TO OBTAIN
Centimeter-Grams	2.54	Inch-Grams
Centimeter-Grams	72	Inch-Ounces
Inch-Ounces	16	Inch-Pounds
Inch-Pounds	12	Foot-Pounds
MULTIPLY	**BY**	**TO OBTAIN**
Inch-Grams	2.54	Centimeter-Grams
Inch-Ounces	72	Centimeter-Grams
Inch-Pounds	16	Inch-Ounces
Foot-Pounds	12	Inch-Pounds

NOTES:

1. 1 inch = 2.54 centimeters
2. 1 ounce = 28.35 grams

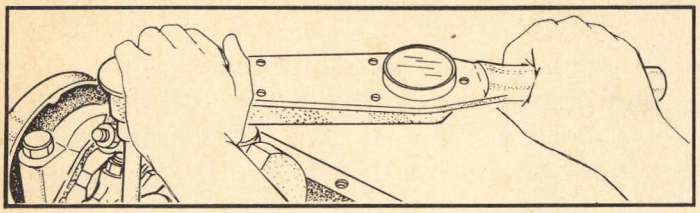
DETERMINING THE CORRECT TORQUE VALUE

There is a correct torque value for tightening every fastener. In some instances, the torque value will be given in the maintenance manual along with the detailed instructions for assembling or installing the components.

The torque wrench should be calibrated in the same torque units—inch-pounds, foot-pounds, inch-ounces, inch-grams, etc.—as you are supposed to use for that specific fastener. Example: If the repair manual tells you to torque a fastener to 40 inch-pounds, then use an inch-pound torque wrench. However, if the torque wrench is not calibrated in the units you need, the units can be converted as shown in table.

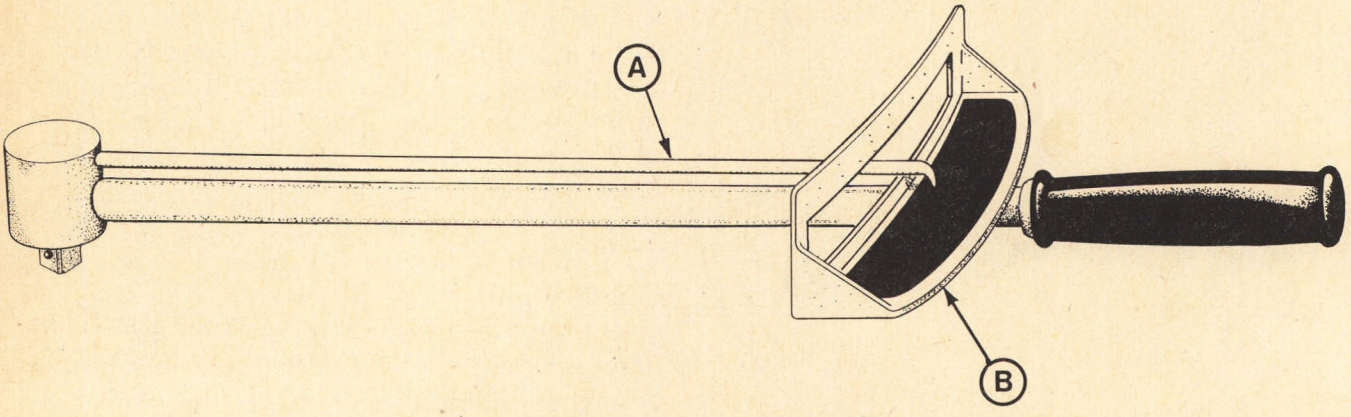
USING THE TORQUE WRENCH

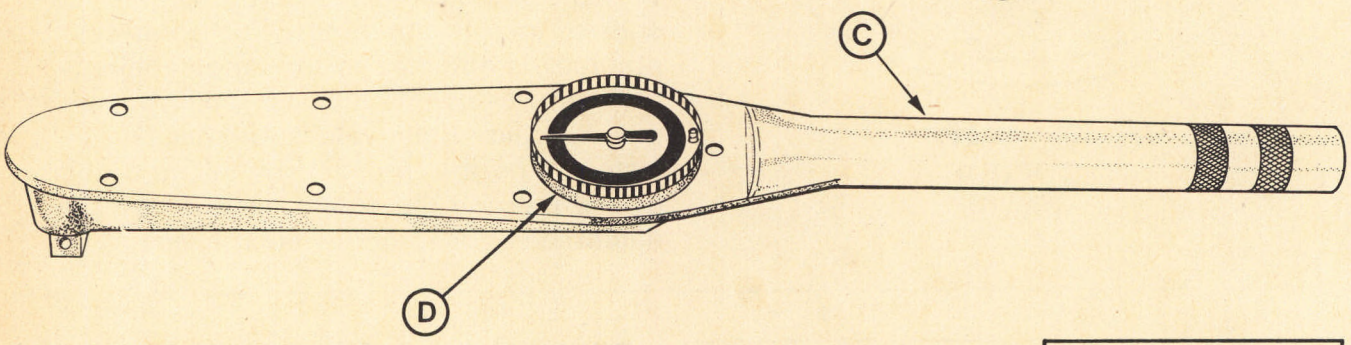
To use a torque wrench properly, you need to know some basic facts concerning torque and must exercise a reasonable amount of care and skill. The facts are as follows:

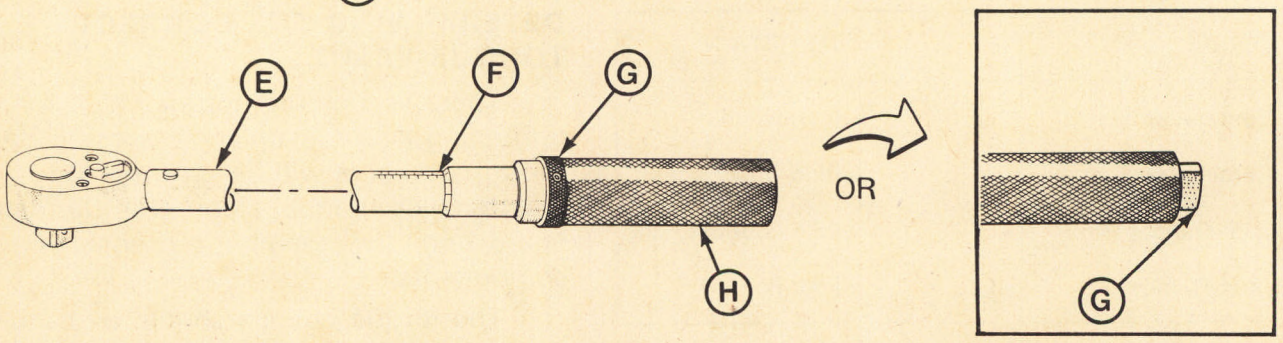


1. *Force application:* A smooth, steady force must be applied to the torque wrench handle to obtain accurate torque values. Exerting rapid or jerky force can result in considerable error in the torque applied.

2. *Reading the torque value:*



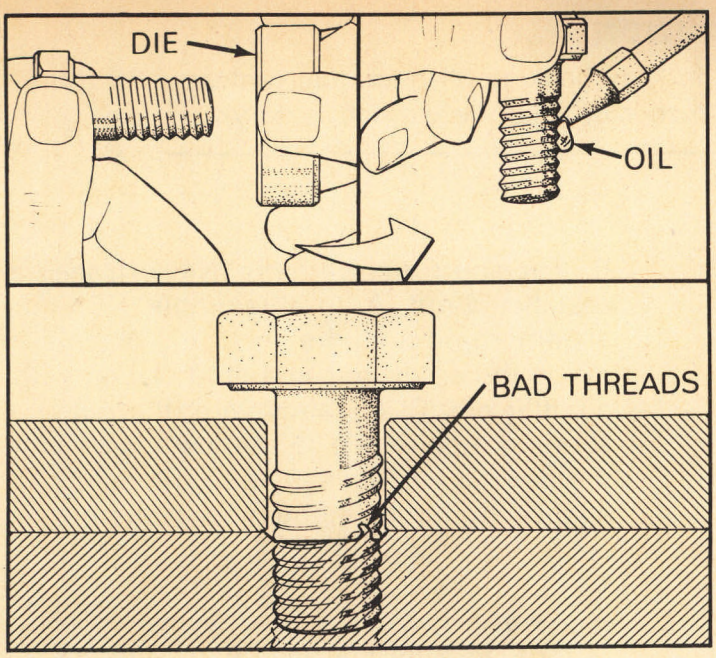




With a deflecting beam torque wrench (A), the torque value is read on the scale (B) as the force is applied to the handle.

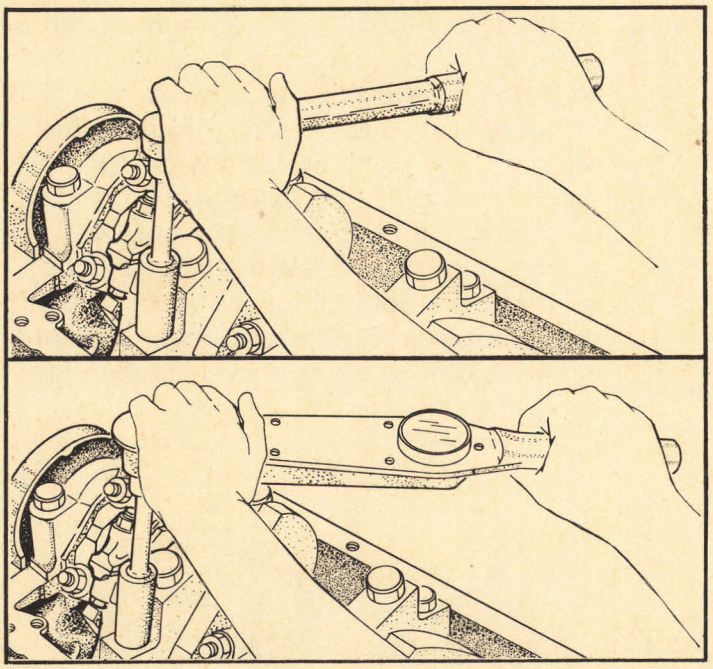
With a dial torque wrench (C), the dial (D) must be rotated and placed on zero before applying any force to the torque wrench handle. Sometimes the dial will then be in a poor position to be read, so if your torque wrench has a dial which rotates both clockwise and counterclockwise, you can set the dial at your predetermined torque value rather than zero and apply force to the handle. The indicator pointer will travel from your predetermined torque value back to zero. You will have applied the same amount of torque either way.

With an audible click torque wrench (E), you preset the torque value on the wrench by releasing the lock (G) on the handle and rotating the micrometer barrel (H) clockwise or counterclockwise to the desired torque setting (F). The lock must be relocked once the setting has been made.

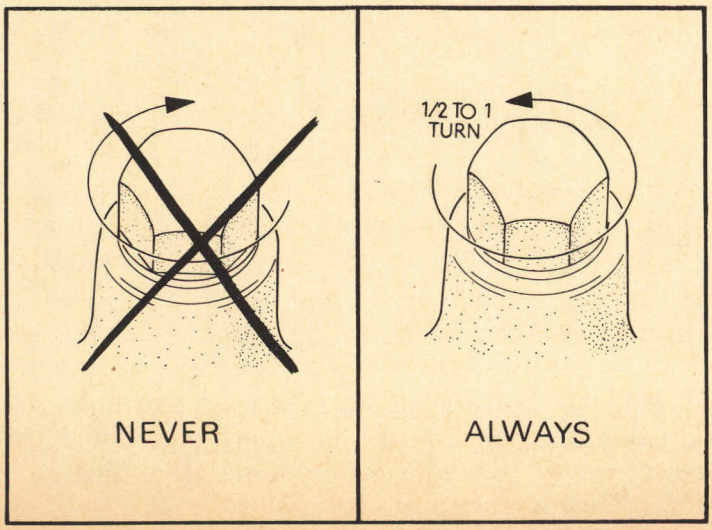


3. *Thread lubrication:* Threads of fasteners must be clean and free of nicks, burrs, paint or heavy grease to obtain the correct torque value. A good lubricant or anti-seize compound should be used on the threads prior to installing the fastener. Light oil or graphite-type lubricants work just fine.

4. *Damaged threads:* Studs, bolts or nuts with damaged threads should be replaced or new threads cut. If you feel you can succeed in installing a nut on damaged threads or a damaged bolt or stud in a hole, you must take into account not only possible damage to the parts you are assembling but the added run-down or tightening resistance you will encounter, which adversely affects torque.



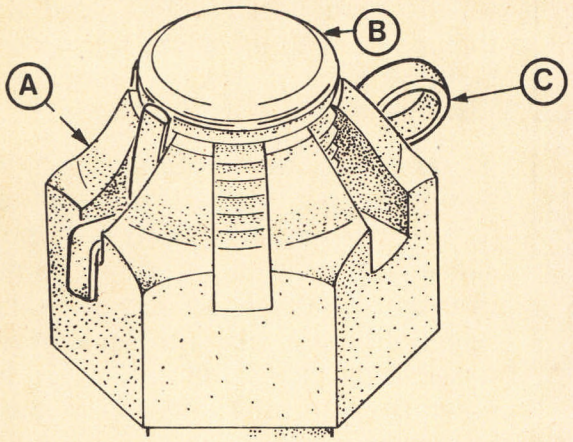
The run-down resistance should be measured on the last full rotation of the nut or bolt. Using a socket wrench, tighten the fastener until you feel there is approximately one more full rotation left before the fastener becomes fully secured. Place your torque wrench on the fastener. Keeping an eye on the torque wrench indicator, turn the fastener that one last revolution, noting the torque value. With this information, you can now determine what the final torque value should be, following this example: If you need 325 inch-pounds of torque on the fastener and the run-down resistance due to thread damage is 25 inch-pounds, the fastener should be torqued to 325 inch-pounds plus 25 inch-pounds, or a total of 350 inch-pounds.



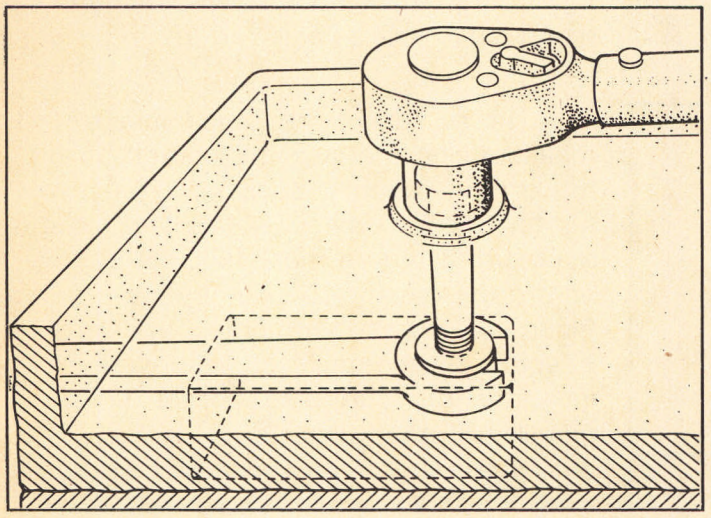
5. *Checking fasteners for torque applied:* An accurate check of already-tight fasteners to determine if they have been tightened to a specific torque value is *not* possible. A fastener that has been tightened to a specified torque value requires approximately 10% more torque than was originally applied to overcome friction and start the fastener turning again. When there is doubt as to whether a fastener has been tightened to the correct torque value, the fastener should be loosened approximately ½ to 1 full turn and retorqued to the correct torque value.

CAUTION

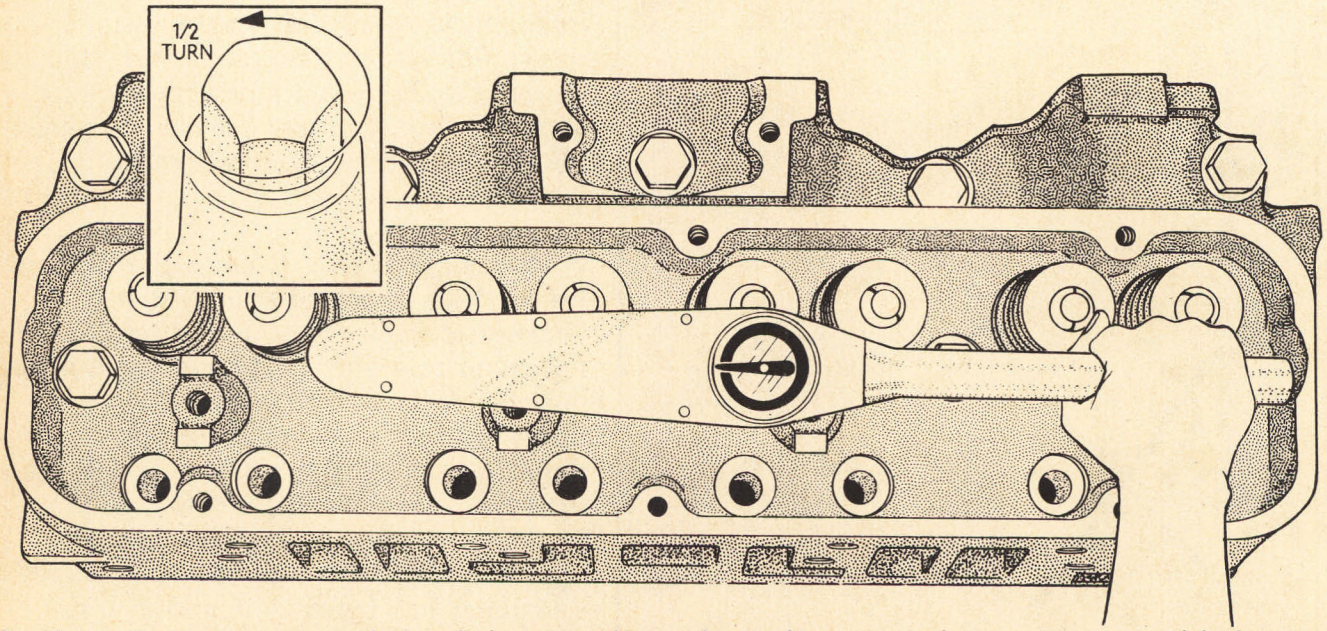
Do not use your torque wrench for any backing-off operation (unless, of course, you are the proud owner of a torque wrench factory).



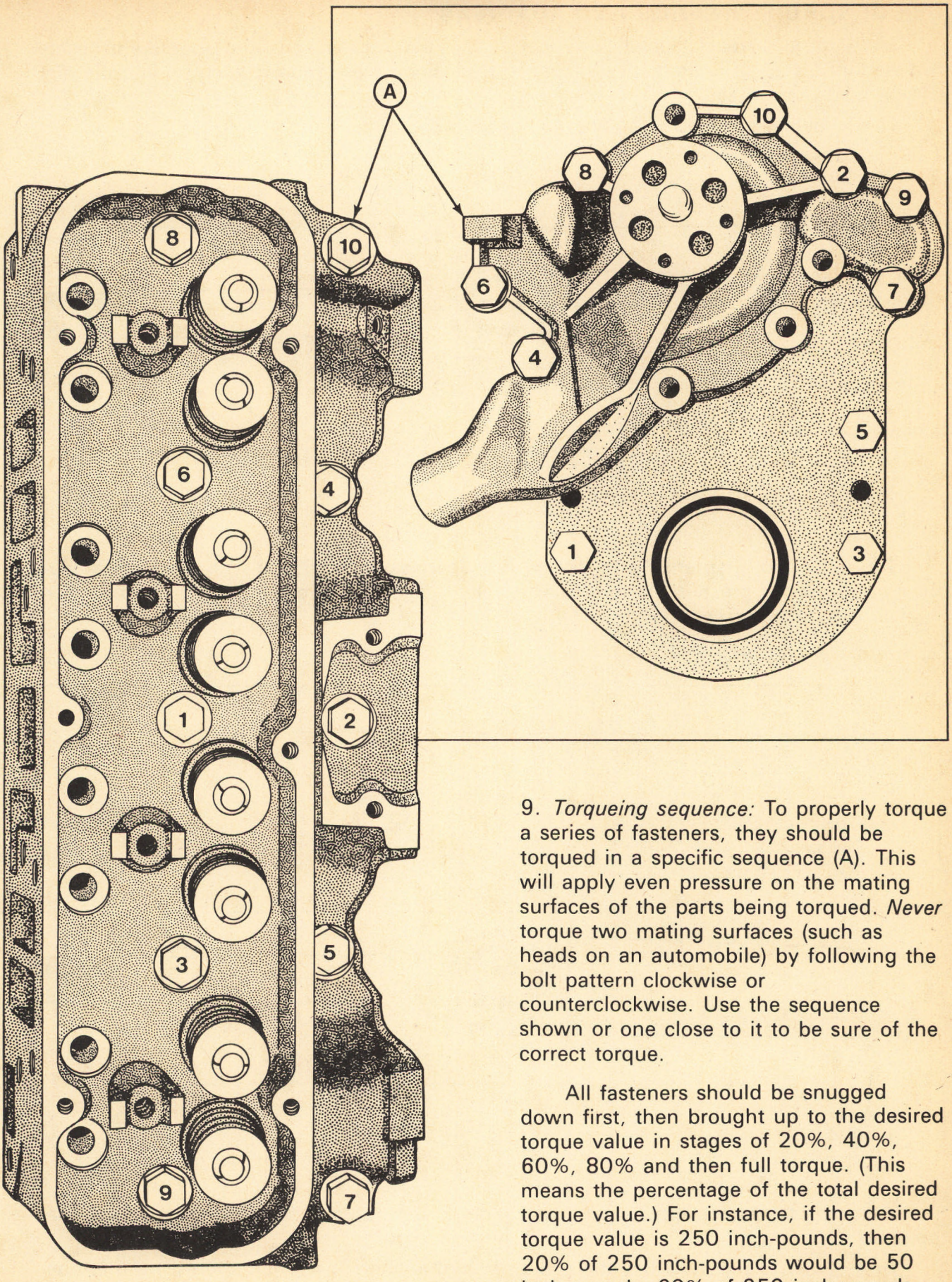
6. *Aligning for cotter pins:* Never *loosen* a castellated nut (A) to obtain hole alignment on a stud or bolt (B). When a nut is to be secured to a stud or bolt with a cotter pin (C) or safety wire, the nut should be tightened to the low range of the desired torque value and the hole aligned by further tightening of the nut.



7. *Torqueing the bolthead:* When a bolt is torqued from the head end, some of the torque applied is absorbed in turning the bolt in the hole. The amount of torque absorbed varies, depending on the clearance in the hole and the alignment of the parts. For this reason, torque values are given for tightening bolts on the nut end. If an occasion arises when the nut end on a bolt cannot be reached with a torque wrench and the bolthead must be torqued, the bolt should be tightened to the high range of the torque value desired while holding the nut end securely with some type of wrench.



8. *Torqueing new nuts or bolts:* It is a good practice, when torqueing new nuts and bolts, to first tighten the fastener to the desired torque value, then loosen the fastener by backing it off approximately ½ turn and finally retorqueing it to the desired torque value. This aids in cleaning and smoothing the threads and results in a more accurate torque.



9. *Torqueing sequence:* To properly torque a series of fasteners, they should be torqued in a specific sequence (A). This will apply even pressure on the mating surfaces of the parts being torqued. *Never* torque two mating surfaces (such as heads on an automobile) by following the bolt pattern clockwise or counterclockwise. Use the sequence shown or one close to it to be sure of the correct torque.

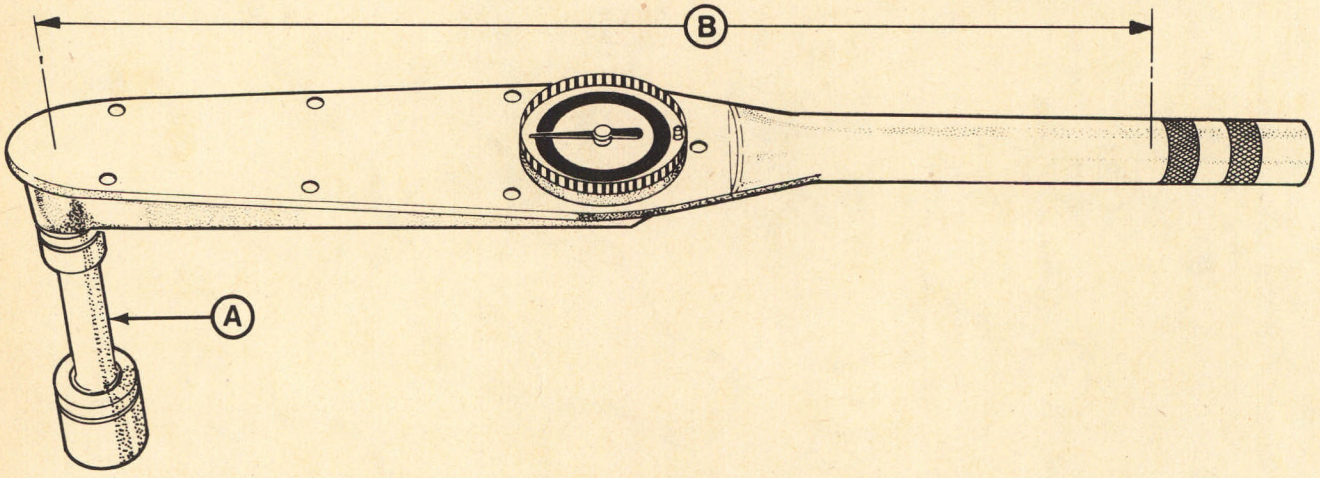
All fasteners should be snugged down first, then brought up to the desired torque value in stages of 20%, 40%, 60%, 80% and then full torque. (This means the percentage of the total desired torque value.) For instance, if the desired torque value is 250 inch-pounds, then 20% of 250 inch-pounds would be 50 inch-pounds. 60% of 250 inch-pounds would be 150 inch-pounds, and so on until full torque value is reached.

USE OF TORQUE WRENCH AND ADAPTERS

Many torque wrench applications require the use of extensions and adapters to reach fasteners in places of limited accessibility or to position the torque wrench so that the dial can be read more easily.

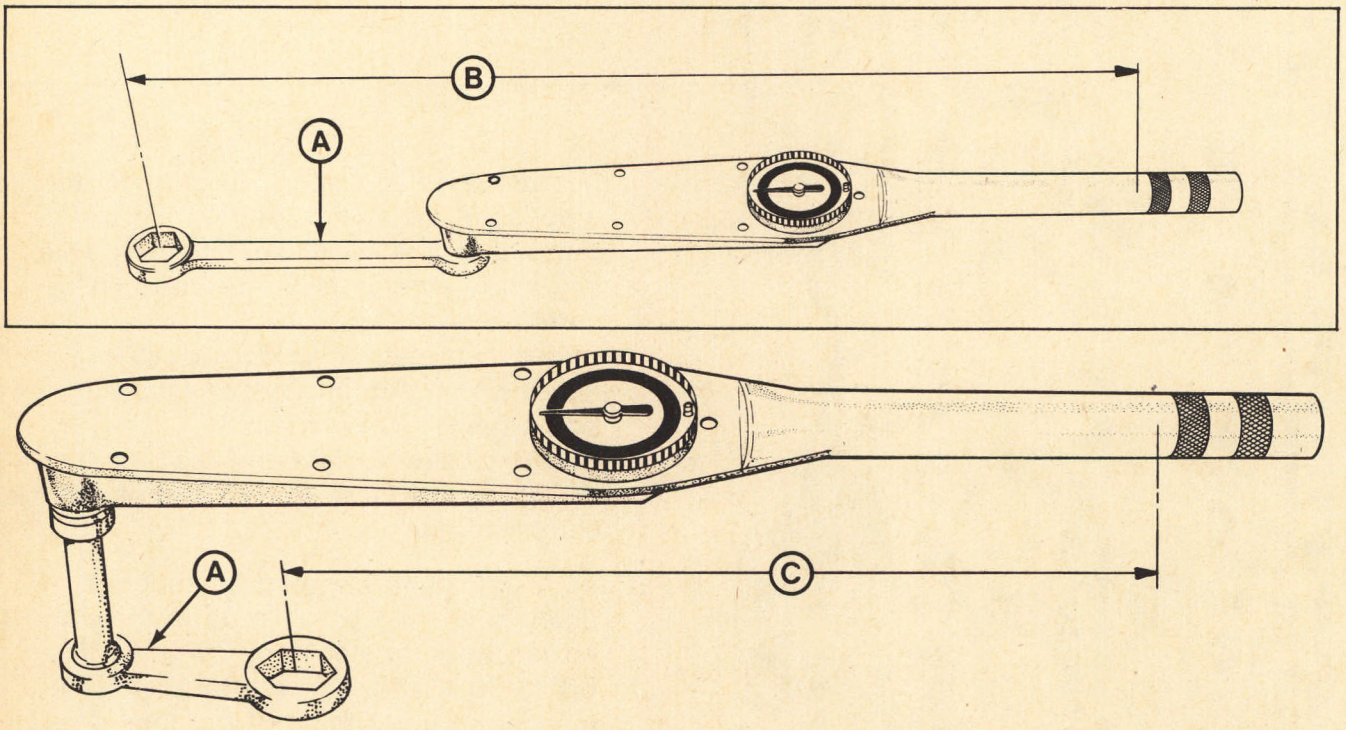
The following are the more commonly used adapters:

1. *Straight vertical adapter:*



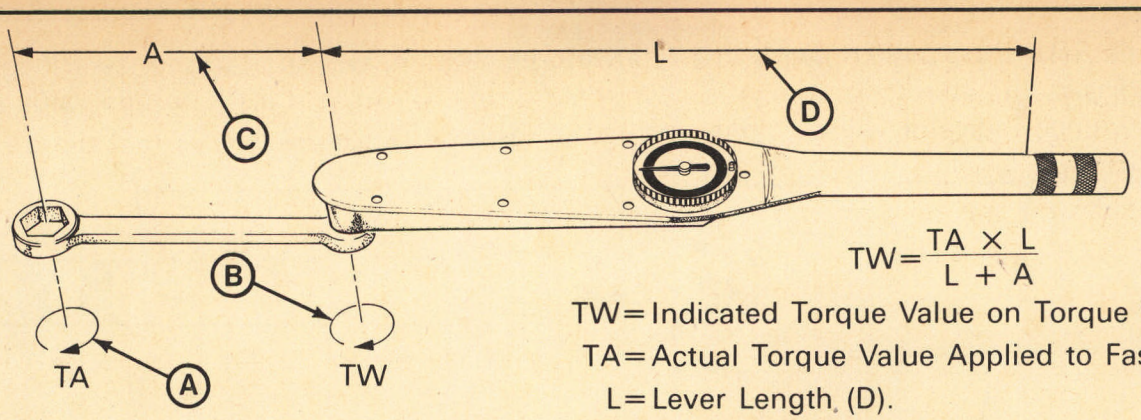
The use of an adapter or extension which operates vertically (A) with the square drive of the torque wrench presents no particular problem, since the effective *length* (B) of the torque wrench has not been changed.

2. *Horizontal adapters:*



For some torqueing applications, an adapter must be used on the torque wrench that operates not vertically but horizontally (A), with the square drive.

An adapter of this type has the effect of lengthening (B) or shortening (C) the torque wrench. Therefore, the torque value shown on the torque wrench indicator is not the torque that will be applied to the fastener. When using *horizontal* adapters, it will be necessary to make the following calculations to find the effect of the added torque wrench length:



$$TW = \frac{TA \times L}{L + A}$$

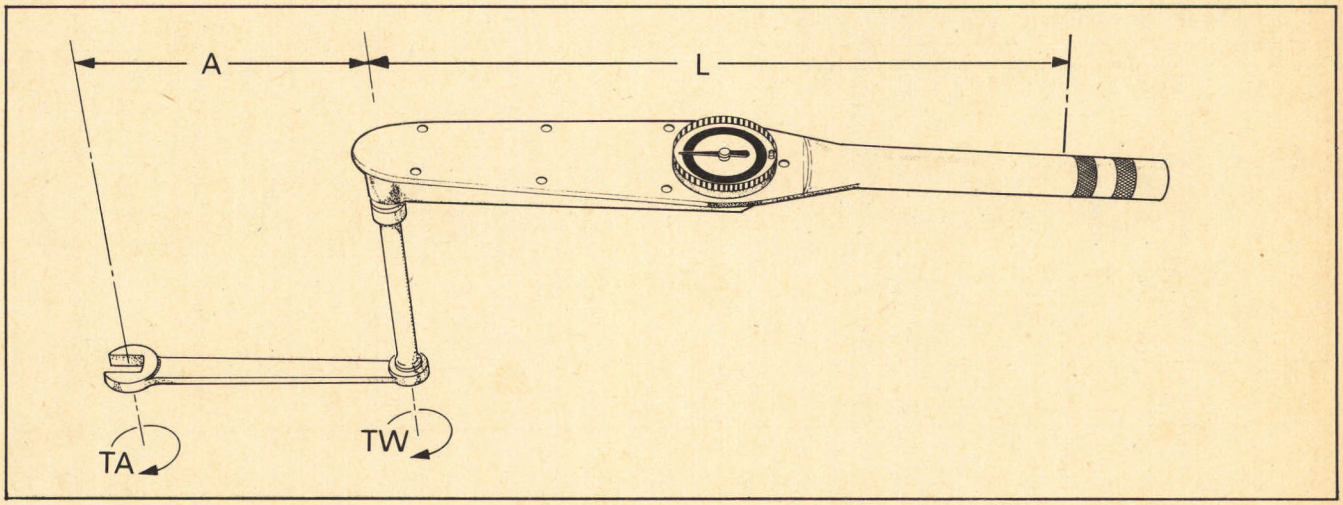
TW = Indicated Torque Value on Torque Wrench (B).
TA = Actual Torque Value Applied to Fastener (A).
L = Lever Length (D).
A = Attachment Length (C).

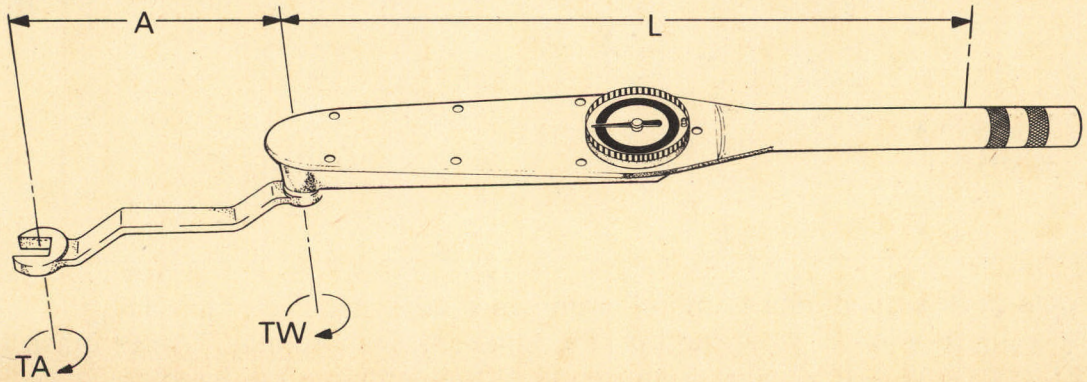
Example: TA = If desired torque is 300 inch-pounds, and
L = 10 inches, and
A = 4 inches, then

$$TW = \frac{300 \text{ inch-pounds} \times 10 \text{ inches}}{10 \text{ inches} + 4 \text{ inches}} = \frac{3{,}000}{14} \text{ or } 214 \text{ inch-pounds}$$

In this example, therefore, when the torque wrench indicator shows 214 inch-pounds, 300 inch-pounds are actually being applied at the fastener (or TA).

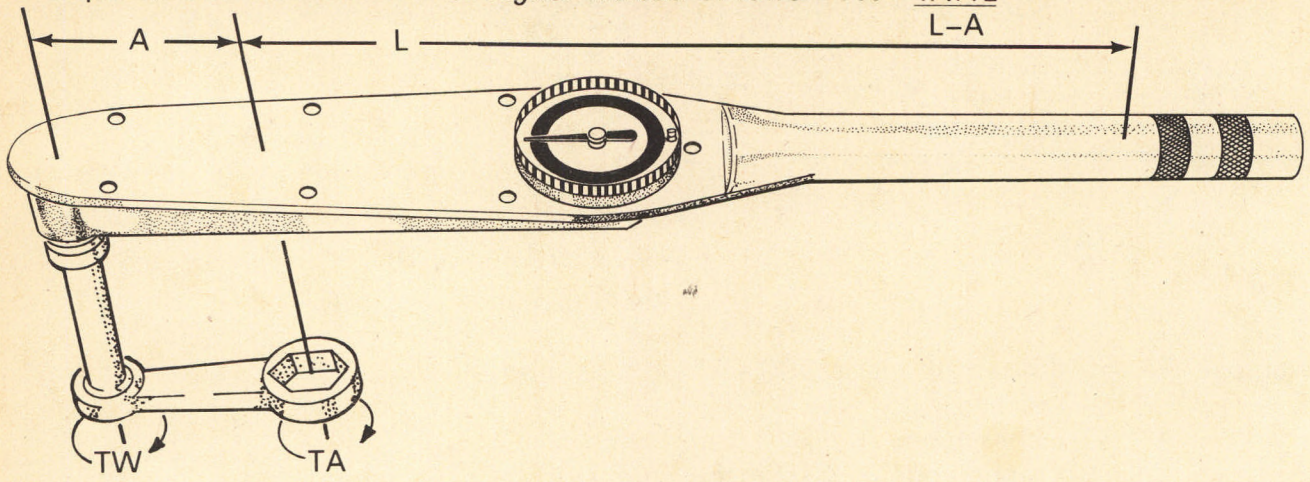
The following drawings show how to use the different types of adapters without changing the previous formula. Nothing has been changed here. Length A is the same as in our first example, even though we are using an extension adapter in the top picture and an offset adapter in the bottom picture.





Our formula for calculating the actual torque will be exactly the same as above: $TW = \frac{TA \times L}{L + A}$

Adapters, when used as shown in the following illustration, will shorten the lever length L. In these cases, the adapter length A is *subtracted* in the formula, and the torque value on the torque wrench indicator will be *higher* instead of lower: $TW = \frac{TA \times L}{L-A}$

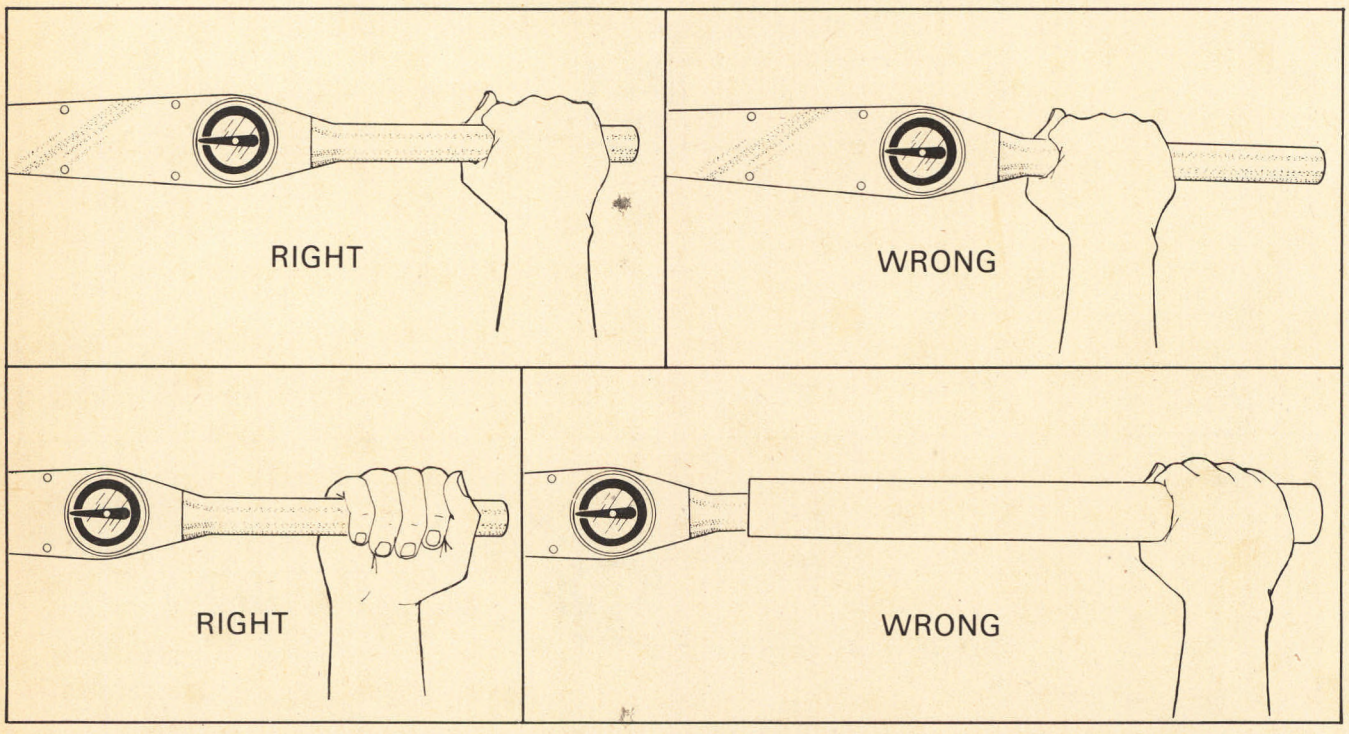


Example: TA = If desired torque is 240 inch-pounds, and
L = 10 inches, and
A = 2 inches, then

$$TW = \frac{240 \text{ inch-pounds} \times 10 \text{ inches}}{10 \text{ inches} - 2 \text{ inches}} = \frac{2{,}400}{8} \text{ or } 300 \text{ inch-pounds}$$

In this example, therefore, when the torque wrench indicator reads 300 inch-pounds, you have reached an actual 240 inch-pounds at the fastener (or TA).

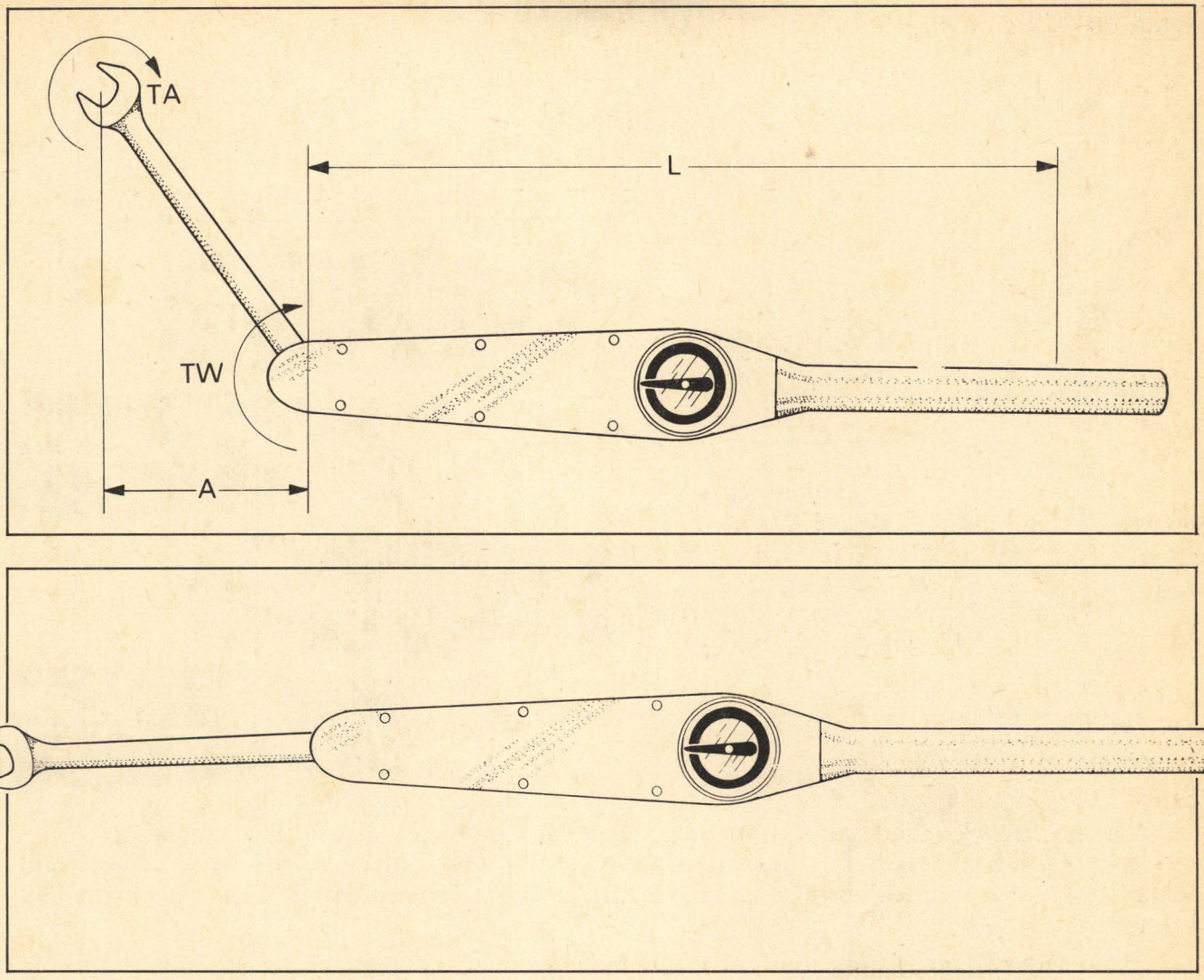
As you can see, the lever length L is the critical factor when using these formulas. Change that length and you change the desired torque value.



At this point it is a good idea to mention one very important factor in using the torque wrench. This is the position of your hand on the torque wrench handle. *Always* grasp the torque wrench handle with the palm of your hand at the center of the handle.

Placing your hand too far forward or aft decreases or increases your desired torque value because you change the lever length L.

Angle adapters:



Adapters do not always extend *straight* from the end of the torque wrench. In cases where the centerline of the adapter and the centerline of the torque wrench are not lined up, the *overall* length of the adapter will not be measured as before, but instead as follows:

Example:

If this adapter went straight out from the centerline of the torque wrench, the adapter would measure 8 inches long. But placed at the angle shown and measured as shown, the adapter only measures 4 inches, thus increasing your desired torque value.

The torque formula is the same as mentioned in the previous steps: $TW = \frac{TA \times L}{L + A}$. Only the measurement of the adapter is different.

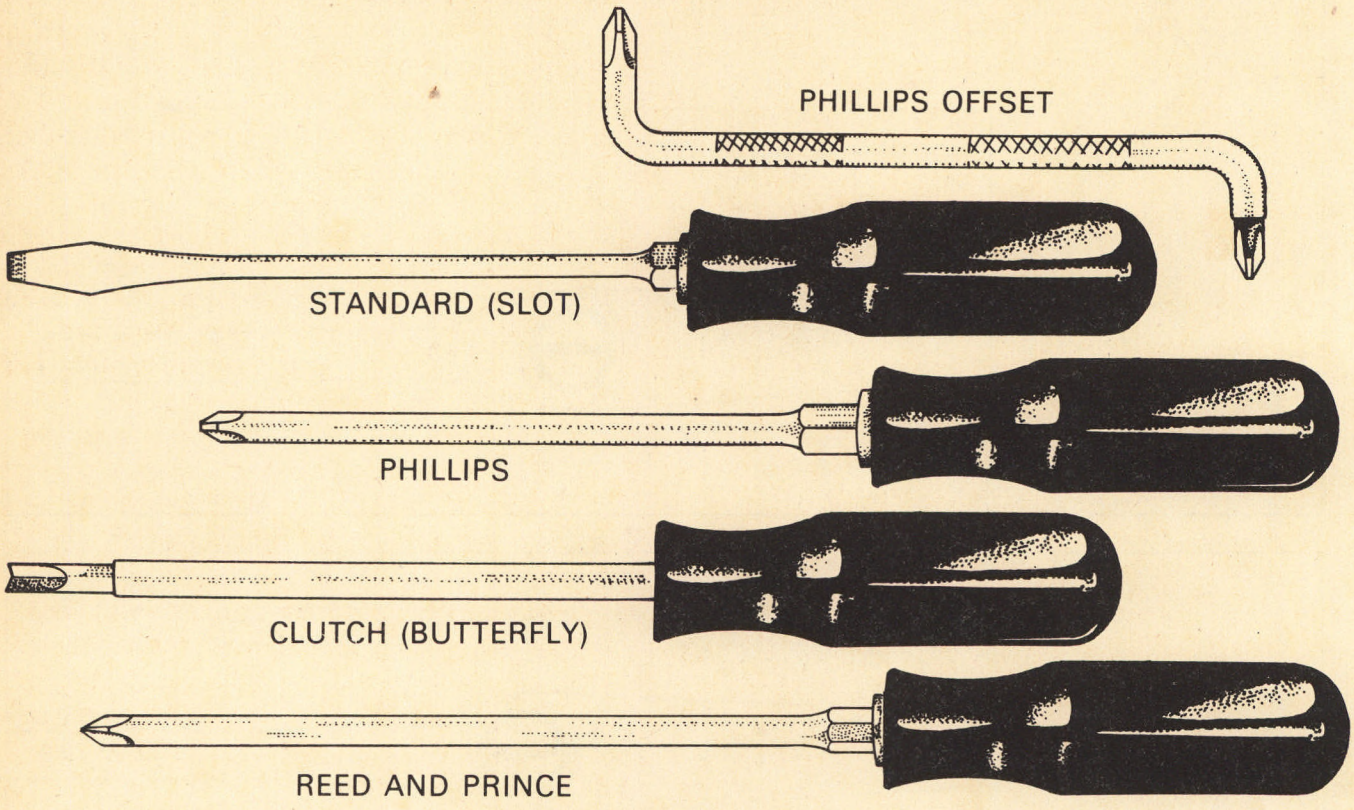
CARE OF TORQUE TOOLS

Remember that any torque wrench is a precision instrument and must be handled with loving care if you expect it to do the job for you. Torque wrenches should never be carelessly tossed among other tools, but should be stored in a clean, dry place.

With deflecting beam torque wrenches, the frame is the measuring element and should never be altered in any way, such as by filing, etching or stamping. Permanent damage can result.

Never overload (surpass the intended capacity) of your torque wrench. By overloading, you can permanently deform the torque sensing element and ruin the tool.

SCREWDRIVERS

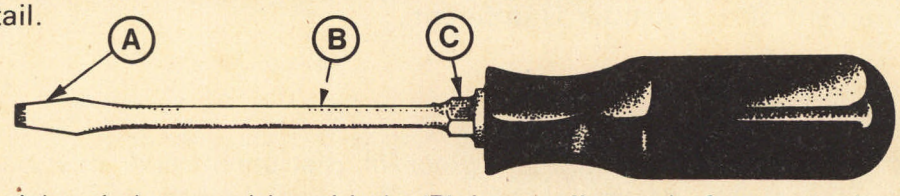


A screwdriver is used for tightening or loosening screws. It is the most abused tool in a non-mechanic's tool box. It has been used as a small pry bar, chisel, can opener, scraper and punch. Using the screwdriver in any way other than its intended use will spoil it for driving screws.

If the screwdriver is improperly used, it may slip and damage the screwhead or the material the screw is in. A screw with a damaged head is usually very hard to remove or install; if you do damage a screw head, it's a good idea to replace it with a new one.

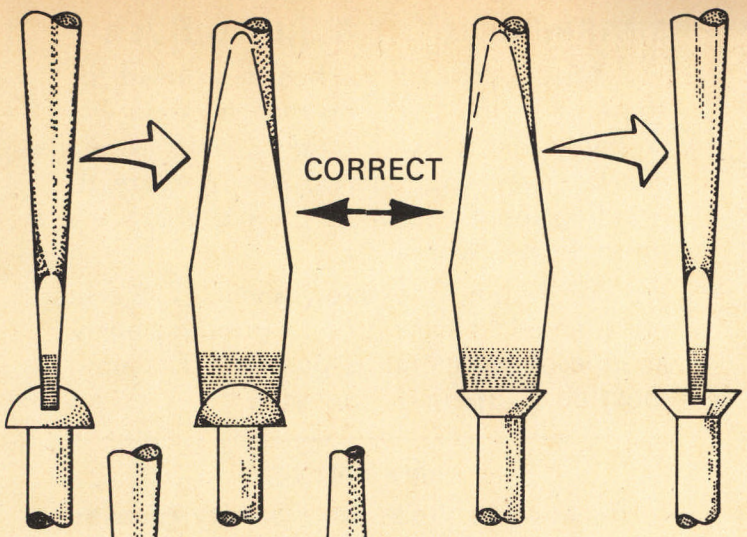
Screwdrivers are made in many sizes and shapes, but all are made for specific jobs. A basic rule in using screwdrivers is to use the right size screwdriver for each job. Realizing that there are many sizes of screws on the market, you can see the reason for the many different sizes of screwdriver.

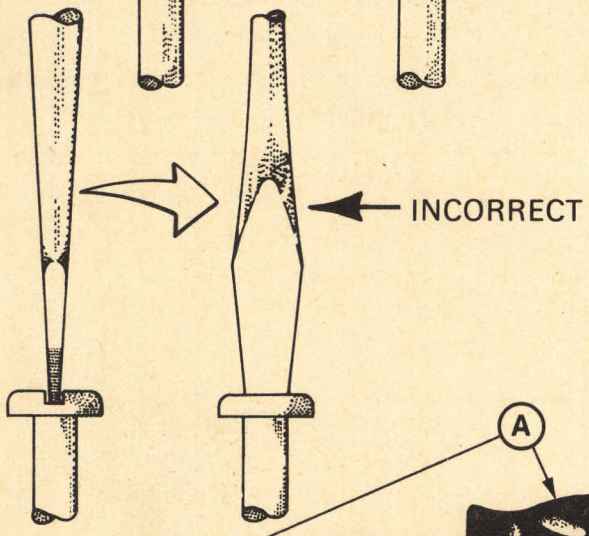
A good mechanic always has a variety of screwdriver sizes in his possession to permit him to accomplish his job easily and fast. Pictured above are just a few of the many screwdrivers available to the mechanic, and as we progress into the text, we will discuss each one in more detail.



The standard (or slot) screwdriver blade (B) is usually made from round stock having a flattened tip (A) to fit screw slots. Most screwdrivers come with plastic or wooden handles, depending on their intended use.

Some standard screwdrivers are made with square blades for added strength so that a wrench may be applied to assist in removing a tight screw. However, some round-bladed screwdrivers are made with a hex shank (C) so that a wrench can also be applied for additional leverage.



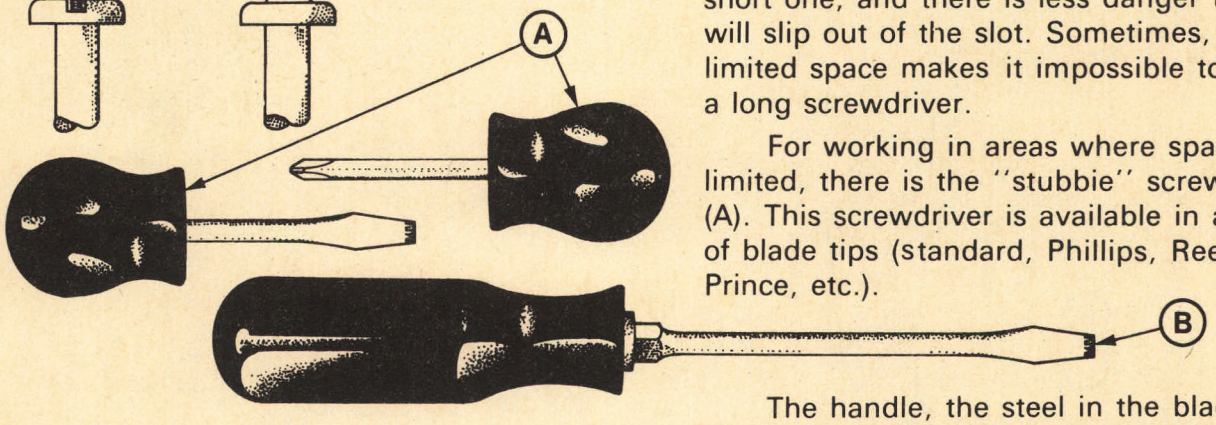


The size of the screwdriver is indicated by the length of the blade—all in inches. Example: A 4-inch screwdriver has a blade four inches long, an 8-inch screwdriver has a blade eight inches long, etc. The width of the blade will also vary. As a general rule, use a screwdriver with a tip equal to the width of the head of the screw. Remember, there is no such thing as an all-purpose screwdriver. The screwdriver *must* fit the screw.

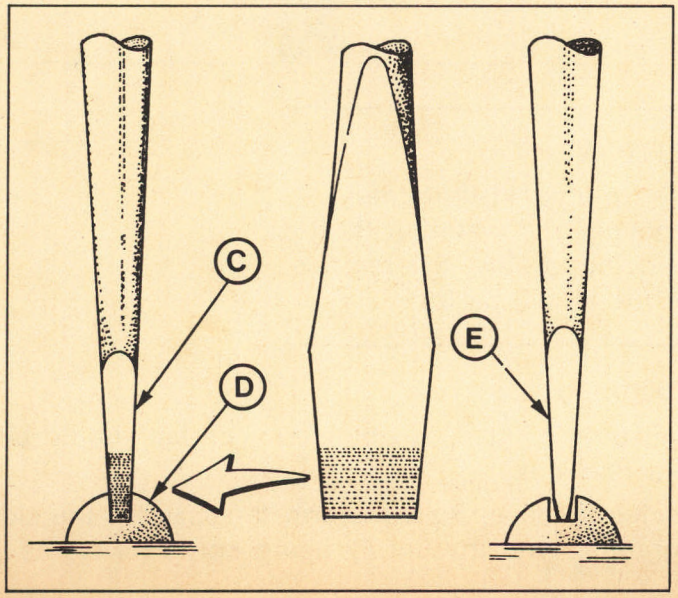
Using a screwdriver whose blade is too large for the screw slot will prevent the blade from entering the slot completely and will damage the screwhead when an attempt is made to turn it. Using a screwdriver whose blade is too small for the screw slot may result in damage to the screwdriver and to the screw slot.

More power can be applied with less effort with a long screwdriver than with a short one, and there is less danger that it will slip out of the slot. Sometimes, though, limited space makes it impossible to use a long screwdriver.

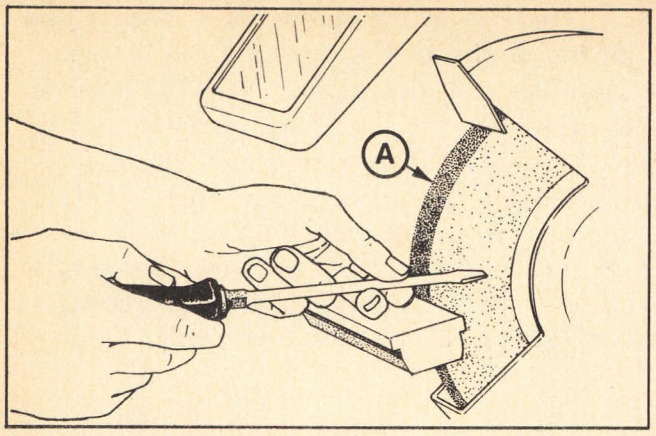
For working in areas where space is limited, there is the ''stubbie'' screwdriver (A). This screwdriver is available in a variety of blade tips (standard, Phillips, Reed and Prince, etc.).



The handle, the steel in the blade and the method of construction in a quality screwdriver are superior to the equivalent parts in a cheap tool. The blade of better steel will not twist or burr easily, and the handles are more securely fastened to the blade. Moreover, the tip of a good screwdriver is ground so that the sides (C) are almost parallel to the sides of the screw slot (D). A blade (E) which widens out from the tip too quickly has a tendency to rise out of the screw slot when attempting to twist the screwdriver. A correctly-ground blade is found only on the more expensive screwdrivers.



A feature worth mentioning here and one that is worth the few extra cents when purchasing a screwdriver is the availability of extra-hardened tips (B). This feature will add many years of use to your screwdriver.



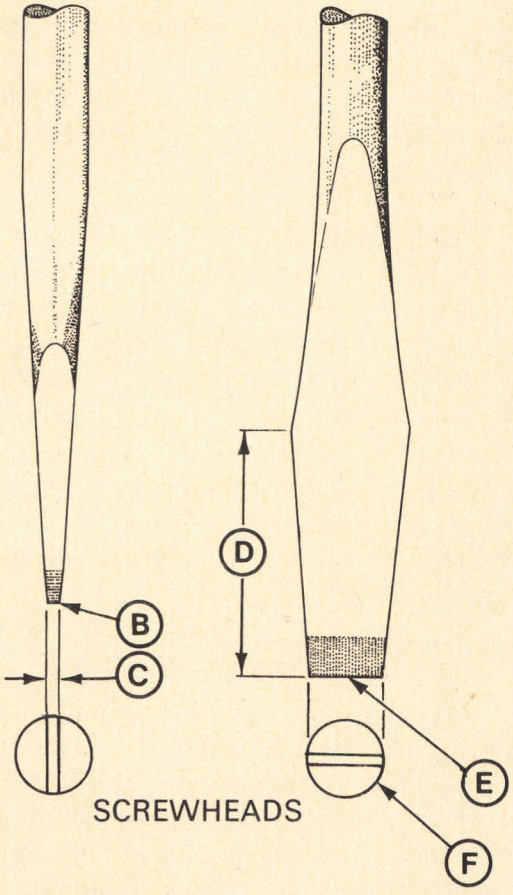
SHARPENING THE SCREWDRIVER

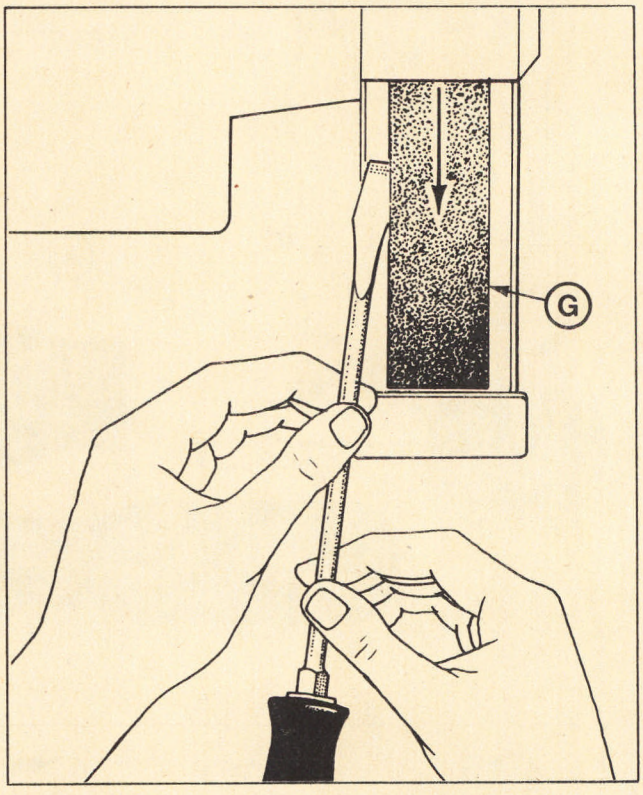
After a screwdriver has been used for some time, the blade tip may become worn so badly that it is no longer usable. New life can be given your screwdriver by correctly grinding the blade tip to the correct shape on an emery wheel (A).

In grinding the screwdriver tip, the first effort should be devoted to grinding away as little of the metal as possible. The tip must be sharpened gradually.

WARNING

Be sure to wear your safety glasses when grinding any material.





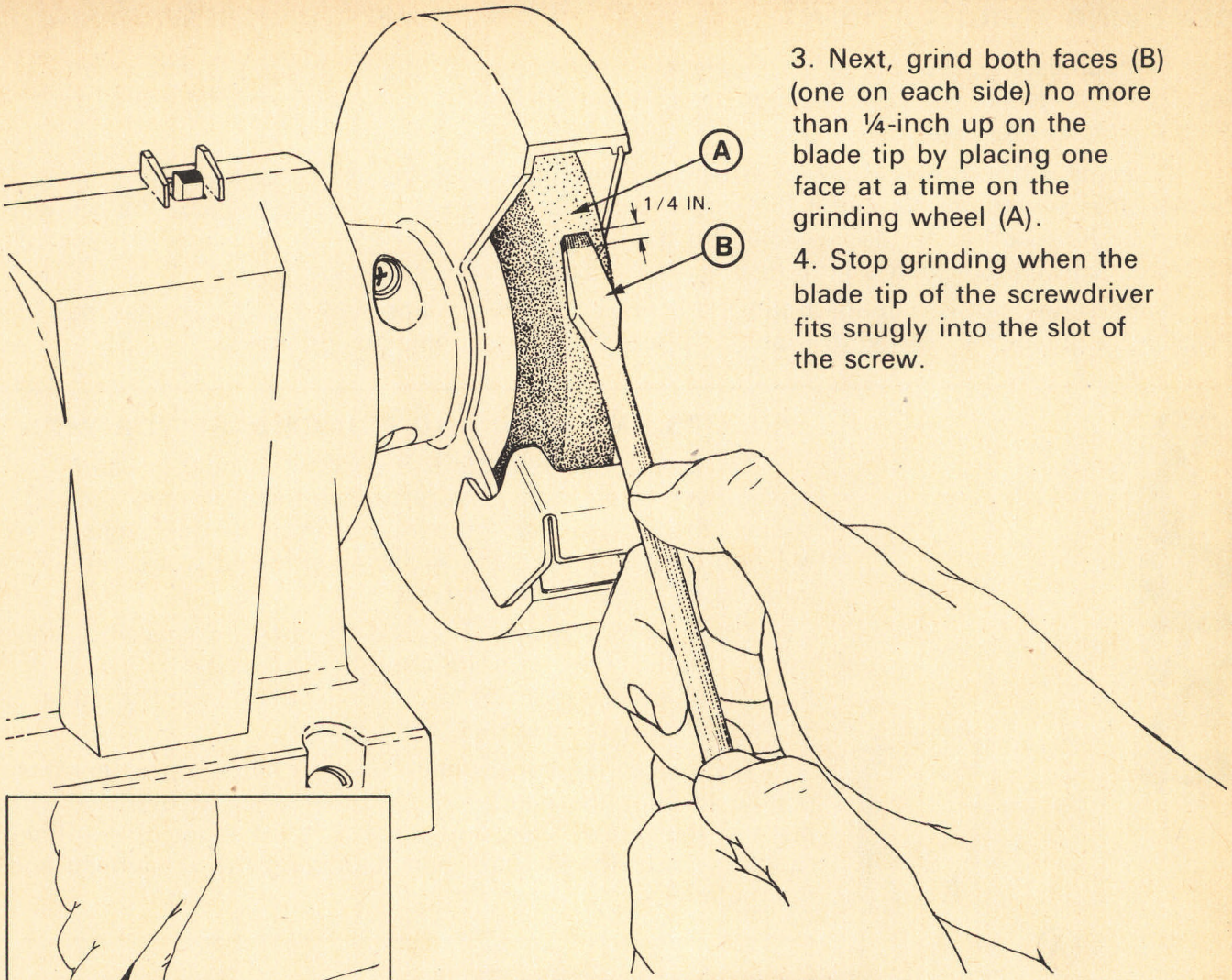
CAUTION

Do not hold the blade tip against the emery wheel too long without cooling it in water. If the tip becomes too hot and is cooled rapidly, the temper (hardness) of the metal will be lost.

The grinding process is accomplished by the following steps:

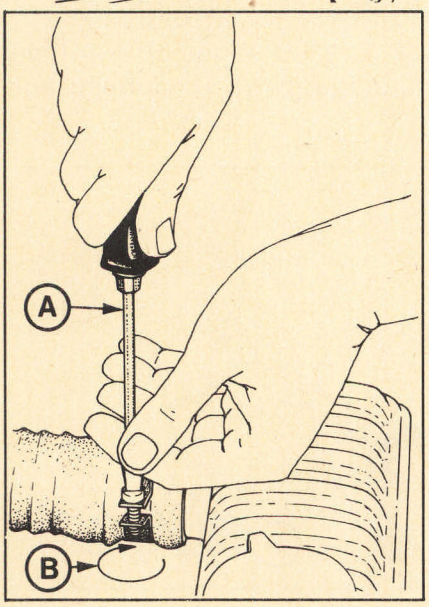
1. Carefully grind the end (B) of the screwdriver until a ''flat'' is obtained. The flat should be equal to the distance (C) at the bottom of the screw slot.

2. Lightly grind both edges (D) (one on each side) of the tip to a uniform taper, using the side of the emery wheel (G). The taper should be gradual, with the tip (E) being only as wide as the screw slot (F).



3. Next, grind both faces (B) (one on each side) no more than ¼-inch up on the blade tip by placing one face at a time on the grinding wheel (A).

4. Stop grinding when the blade tip of the screwdriver fits snugly into the slot of the screw.



USING THE SCREWDRIVER

Always use the longest screwdriver available if it is convenient to perform the job and its blade fits the screw slot. Hold the handle of the screwdriver (A) firmly in the right hand with the head of the handle against the palm. To drive a screw in (or tighten it), turn the screwdriver clockwise (B), which means the same direction that the hands of a clock would move if you were looking down on the face of the clock. Naturally, to remove (or loosen) the screw, you would turn it in the opposite direction, or counterclockwise.

When taking a fresh grip on the handle with the right hand, steady the tip of the screwdriver and keep it pressed in the screw slot with the left hand.

WARNING

If holding the material being worked on in the hand, do not press down on the handle of the screwdriver, as it may slip off and pierce your hand. If working on electrical equipment, be sure all power is off.

When installing a screw, it's a good idea to put a small amount of oil, graphite or soap on the threads. This will prevent rusting and make installation and removal of screws easier.

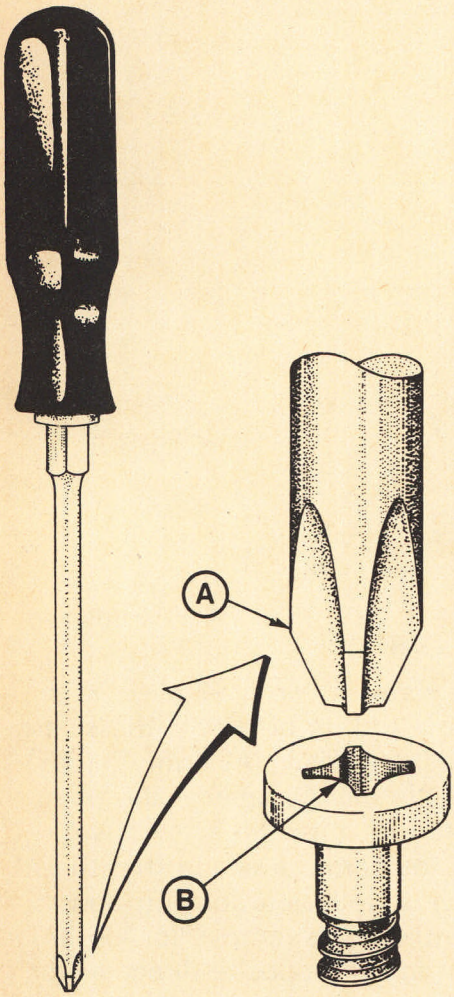
SCREWDRIVERS

REMOVING A TIGHT SCREW

Sometimes a screw will be extremely hard to remove. If this happens, the screw can usually be started if you give a *slight* twist in the tightening (clockwise) direction first and then attempt to remove it.

It seems some screws can be partially loosened and then become impossible to remove further. It is sometimes helpful if the screw is worked both ways. In other words, the screw should be loosened as far as possible and then partially tightened. Each time this is repeated, the screw can be loosened a little further until it can be entirely removed.

If the screw slot is damaged and the screw can only be loosened partially, it may be possible to grasp the head with a pair of pliers or vise-grip pliers to remove it.

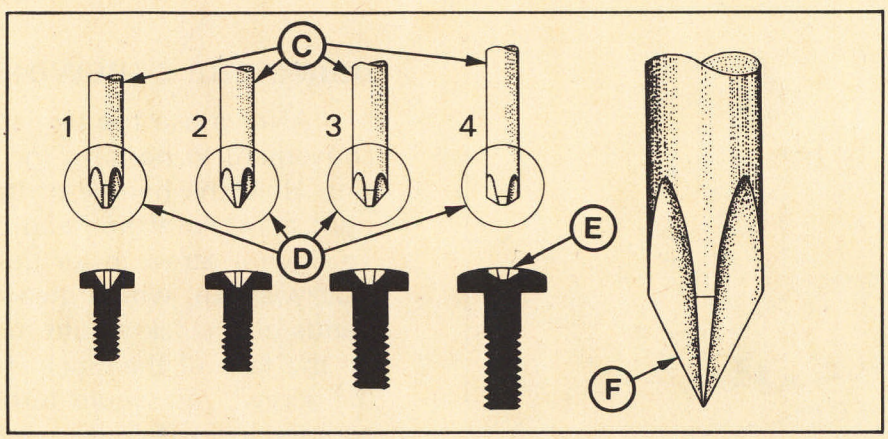


PHILLIPS AND REED AND PRINCE SCREWDRIVERS

The basics discussed in this section on how to use a screwdriver apply to any and all screwdrivers (except, of course, the screwdriver-sharpening portion of this section), so we won't repeat what's already been said but will continue with other types of screwdrivers.

The Phillips screwdriver has a point (A) of special design to fit Phillips screws (a trade name). Such screws have two slots (B) that form an ''X'' in the head. The point of the screwdriver is formed to fit that X.

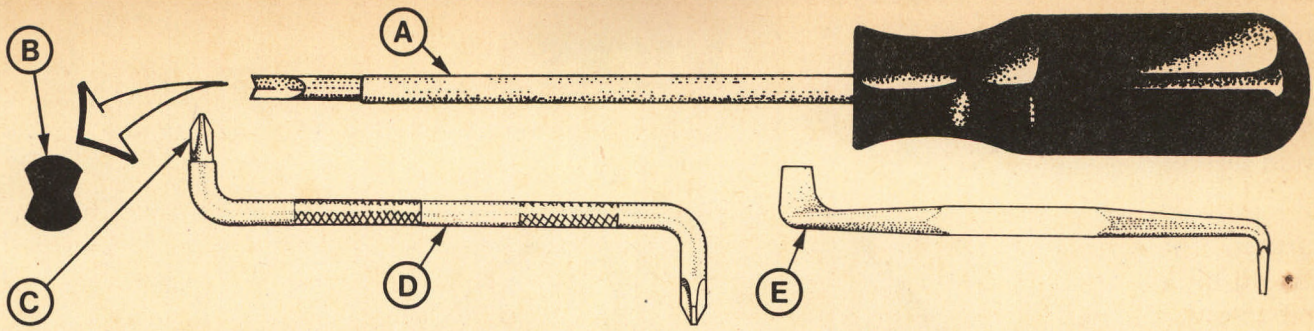
The socket-like construction of the Phillips screw permits greater turning effort to be applied to the screw by the driving point of the screwdriver, and there is less danger of the driver slipping out of the slots (B) and damaging the screwhead and the material.



The Phillips screwdriver is available in different point sizes (C), which are numbered one, two, three and four. The difference in the point sizes is in the degree of taper (D) of the point. Example: The No. 1 Phillips screwdriver is the most pointed of all the screwdrivers. The points gradually become more blunt as the number size becomes larger.

Screws are made to fit these different point sizes of the Phillips and Reed and Prince tips. The internal taper (E) of the screw is made to accept the No. 1 through No. 4 Phillips tips; thus the more holding power required of the screw, the larger the screw will be and the larger the Phillips tip number it will require.

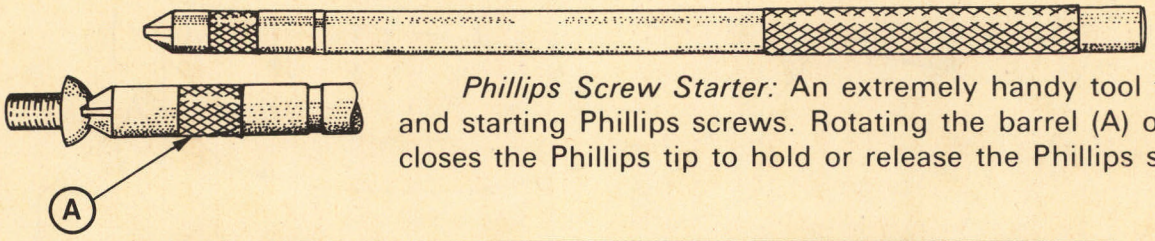
The Reed and Prince tip (F), also a trade name, is similar to the Phillips tips except that it is much more pointed and used only on Reed and Prince screws, the depth of the taper (E) being much deeper. The Phillips tip should *never* be used on a Reed and Prince screw, and a Reed and Prince tip should never be used on a Phillips screw. If you do interchange these screwdrivers, damage to the screw and the screwdriver can result.



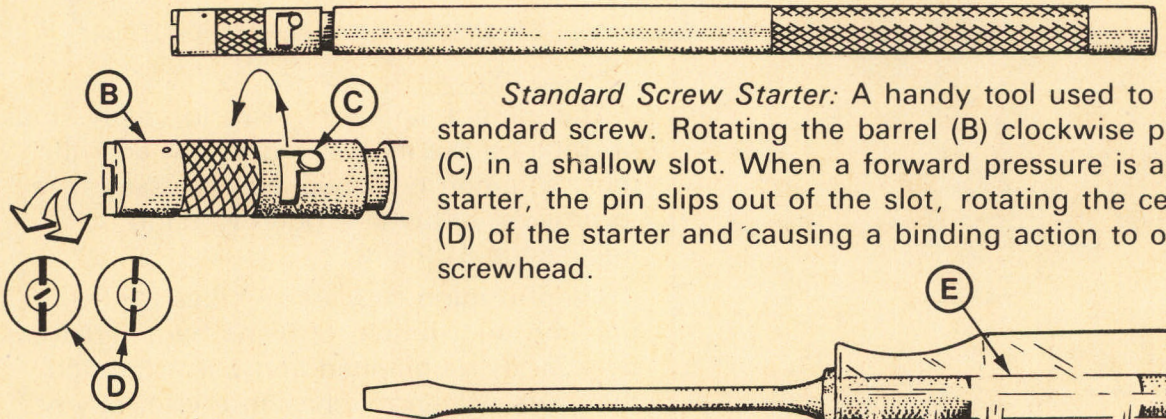
The clutch screwdriver (A), also known as the figure 8 or butterfly, is becoming very popular in the automotive field. This screwdriver is easy to use with less chance of slipping out of the screw slot; and due to the construction of the tip (B), it is extremely strong.

The Phillips offset (D) and standard offset (E) screwdrivers are constructed for those hard-to-get-to areas where a common screwdriver cannot reach. Note that on the Phillips offset, one end is usually longer than the other, with a No. 1 tip (C) on one end and a No. 2 tip on the other. This feature gives you two screwdrivers in one, although the offset Phillips is available with the same size tips on both ends.

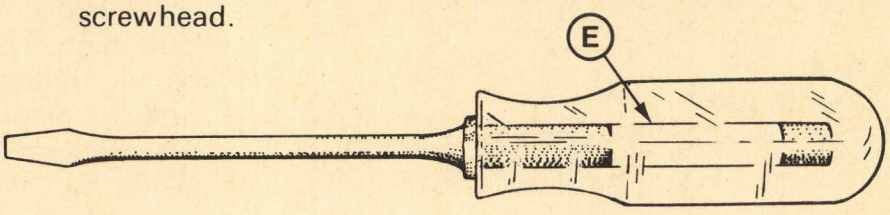
SPECIAL-PURPOSE SCREWDRIVERS



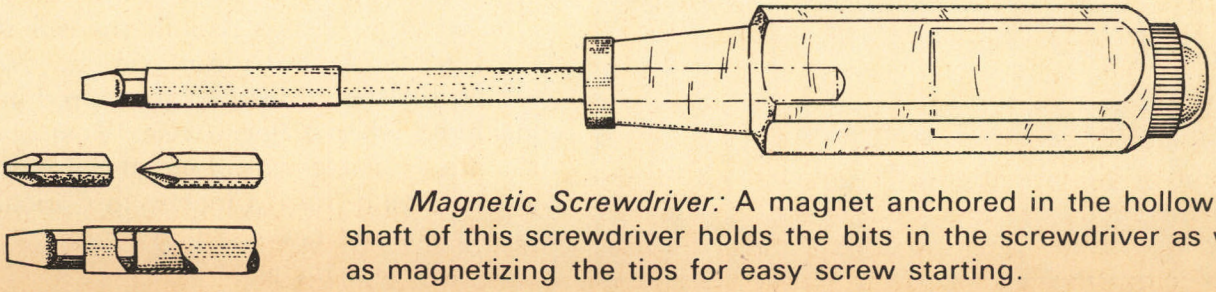
Phillips Screw Starter: An extremely handy tool for holding and starting Phillips screws. Rotating the barrel (A) opens or closes the Phillips tip to hold or release the Phillips screw.



Standard Screw Starter: A handy tool used to start the standard screw. Rotating the barrel (B) clockwise places a pin (C) in a shallow slot. When a forward pressure is applied to the starter, the pin slips out of the slot, rotating the center portion (D) of the starter and causing a binding action to occur in the screwhead.

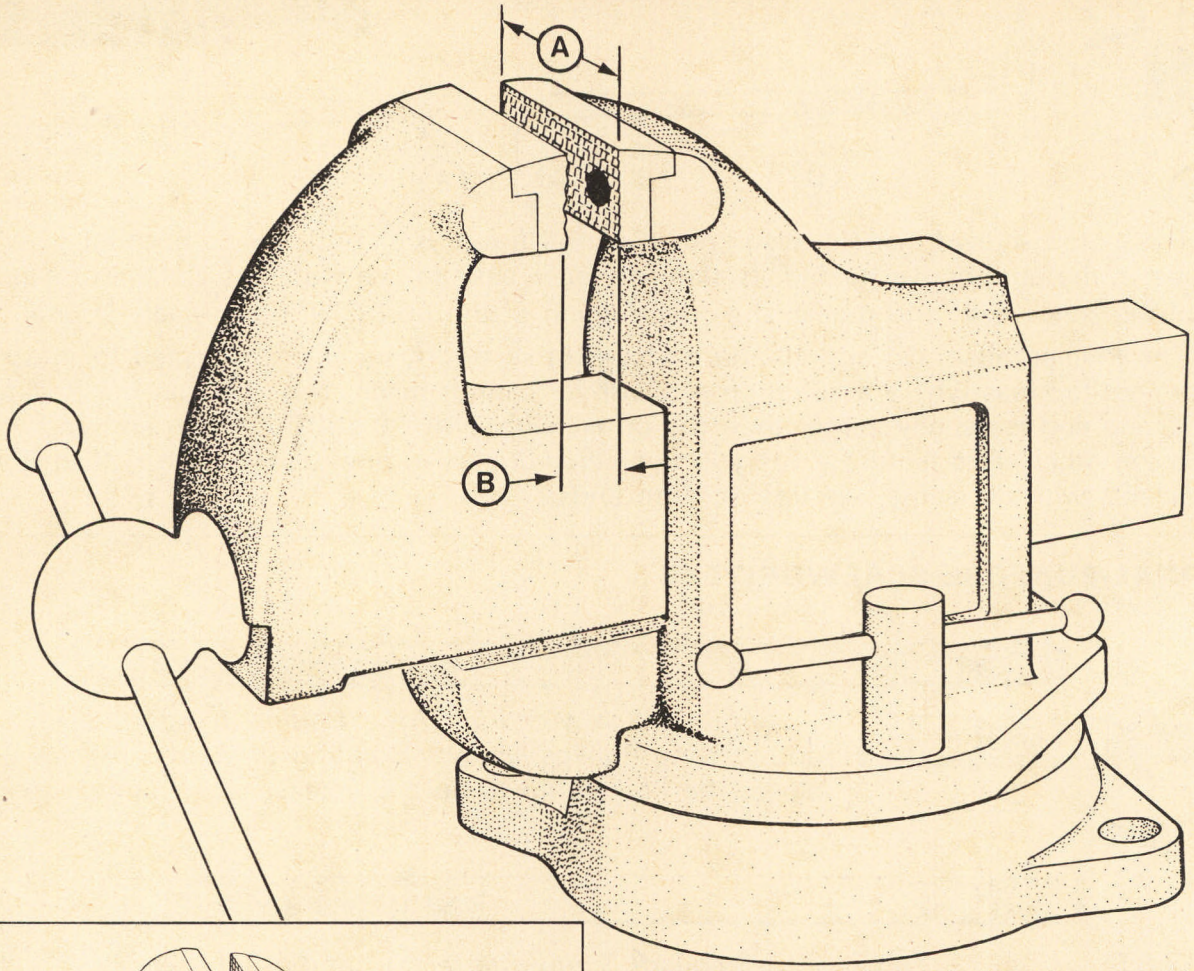


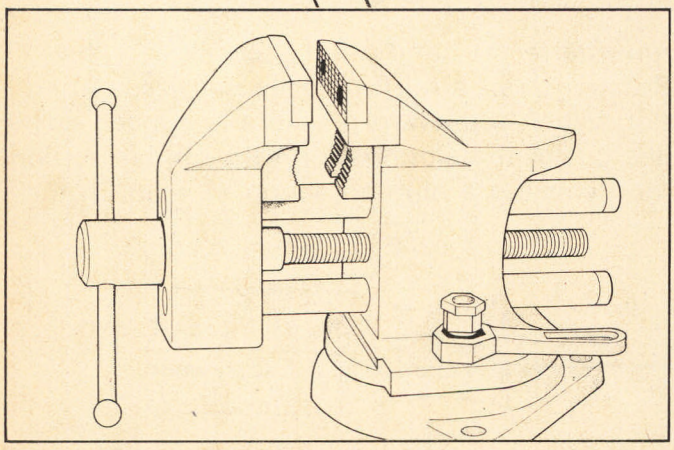
Spark Plug Test Screwdriver: This screwdriver is used to test the condition of spark plugs while the engine is running. It has a neon bulb (E) fitted into the handle. A brilliant flash of the bulb means the plug is good. A weak flash indicates the plug gap is too narrow, and no flash indicates a short in the plug.

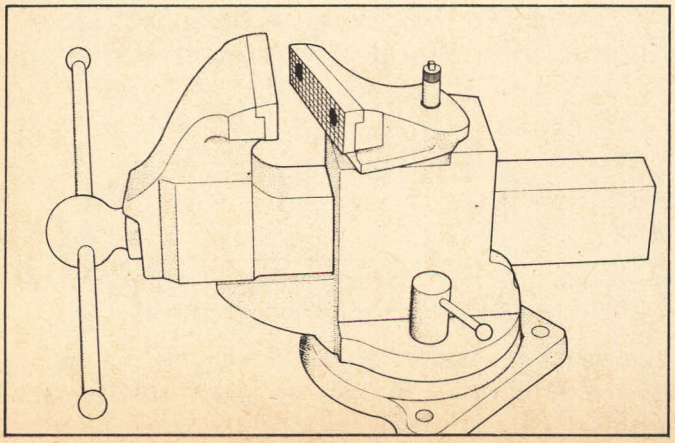


Magnetic Screwdriver: A magnet anchored in the hollow shaft of this screwdriver holds the bits in the screwdriver as well as magnetizing the tips for easy screw starting.

VISES







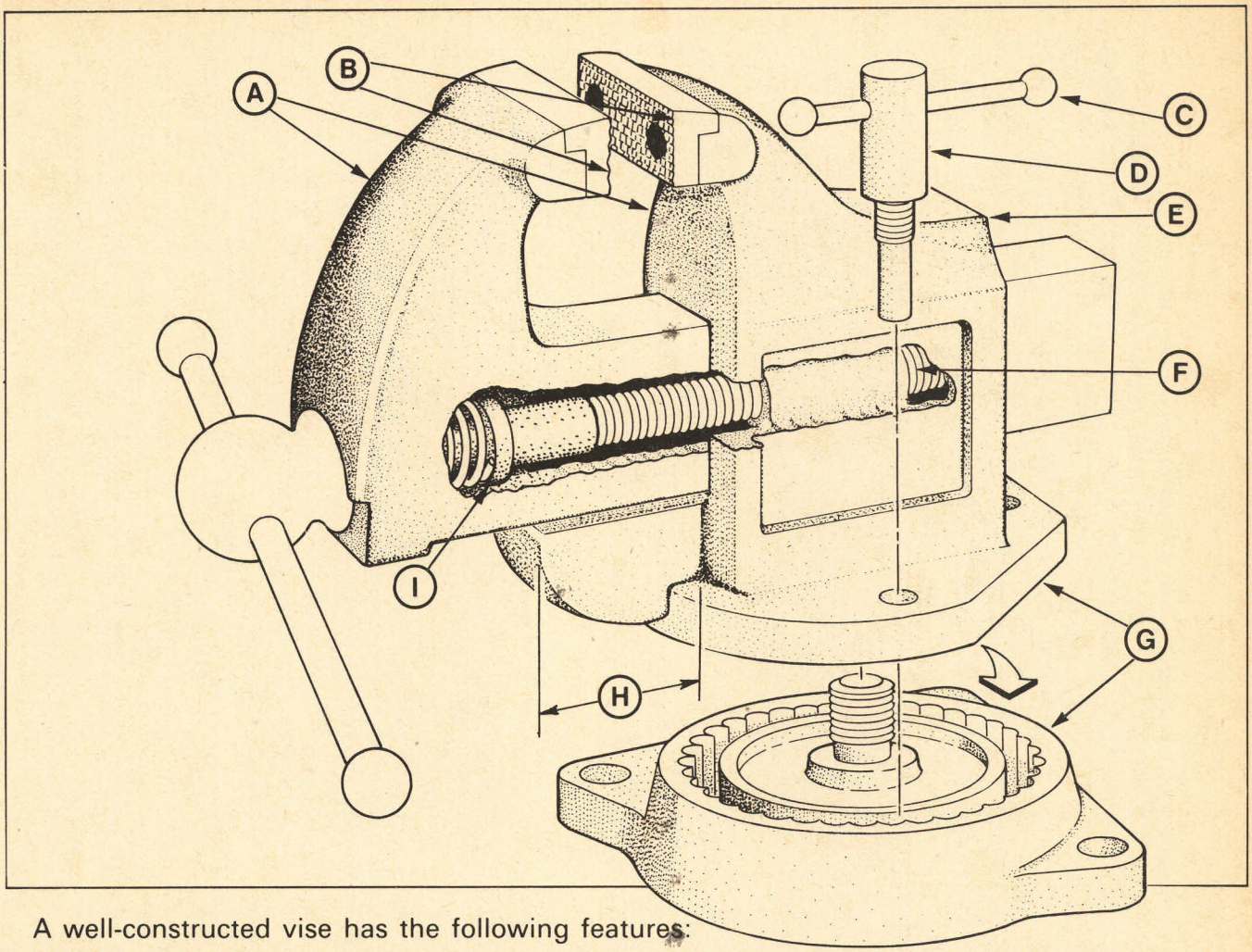
There are a variety of vises for every kind of trade on the market today, but only the most common types will be discussed here to provide you with a good working knowledge of them.

Keep in mind that a vise takes the grueling punishment of being hammered on, twisted, over-tightened and burnt through the years. When purchasing a vise, buy a high-quality, well-made one that will last through years of punishment.

Vises have *one* purpose only, which is to hold material or a part at a bench or tool box while work is being performed on it (assembly, disassembly, welding, filing and so forth).

The size of a vise is usually measured by its jaw width (A), but the maximum jaw opening (B) should also be measured and considered when sizing a vise. Most good vises are available with a variety of jaw widths ranging from 3 inches to 6 inches and a maximum jaw opening ranging from 4 inches to 9¾ inches.

CONSTRUCTION OF VISES



A well-constructed vise has the following features:

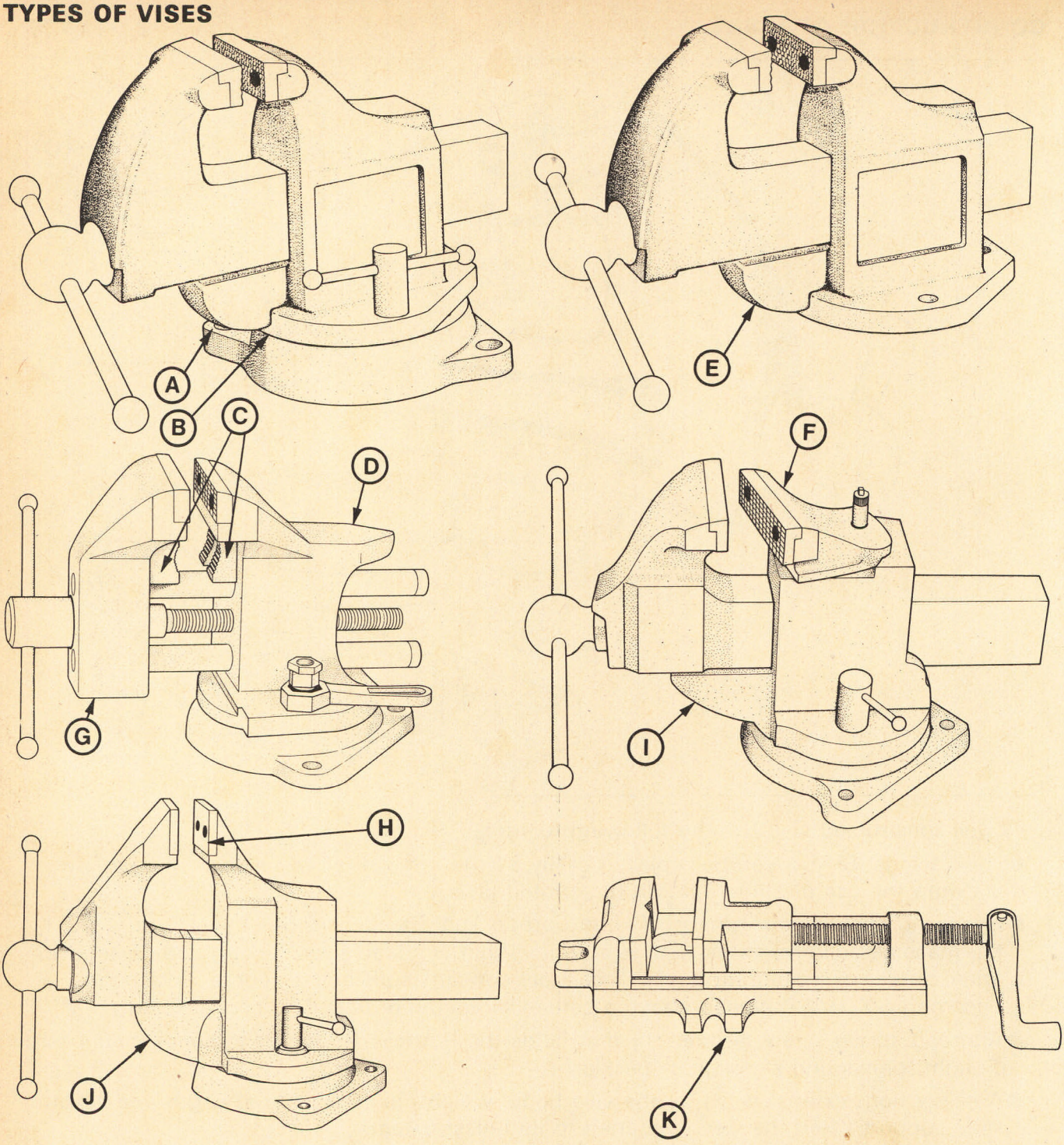
- Jaw facings (B) that can be replaced easily by the removal of two screws in each jaw, allowing the use of either smooth or serrated jaws.
- Front and back jaws (A) made of High Carbon Tool Steel. Tool Steel is a term used in the machine-building industry. It is any steel that is suitable for making cutting tools or other classes of high-grade tools. Tool Steel contains sufficient amounts of carbon to become very hard if heated above a certain temperature and then cooled rapidly.
- A strong spring screw fastener (I) that holds the buttress (strong or fortified) thread screw (F) tight, preventing slippage or backlash.
- A heavy horn extension (H) on the vise body, which provides extra strength and a better slide support when the vise is opened to its fullest extent.
- An overall long-lasting finish (not just a pretty paint job) to protect the vise from rust and abuse.
- A non-slip swivel base (G) and base lock (D), which allow the base lock handle (C) to swing back out of the way after locking. Also, a good vise has the capacity to be converted from a stationary mount base to a swivel mount.
- A well-tempered (having the right degree of hardness) buttress thread screw (F), which will not bind or become stiff when operated.

A special feature that is extremely handy on any vise is the built-in anvil (E). This area is made especially for hammering objects. If the base does not have an anvil area, do not hammer on any other part of the vise.

If your vise has all the features mentioned above, you own a good vise which should last for many, many years.

VISES

TYPES OF VISES



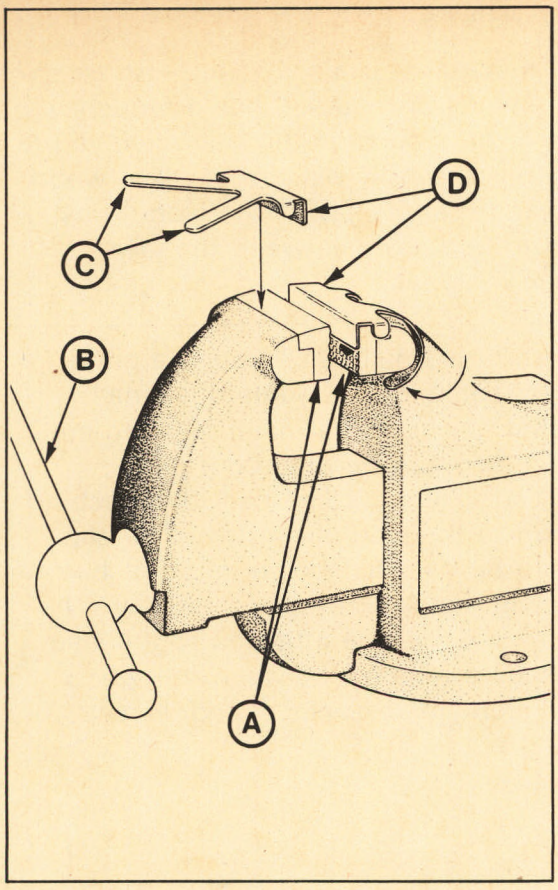
Vises (A) and (E) are exactly the same, except that vise (A) has a swivel base (B), which allows work to be done from different angles.

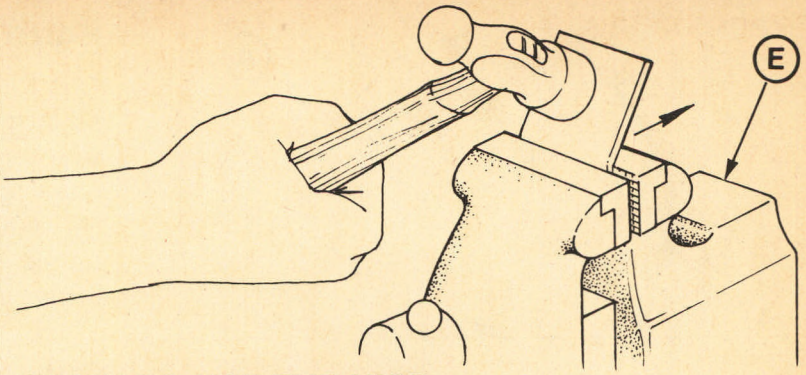
Vise (G) is the best all-around vise for the mechanic. It has an anvil (D) for hammering and a special set of replaceable jaws (C) for holding pipe or other parts. This vise can also be rotated at its base.

Vise (I) has a swivel rear jaw (F) for work with tapered parts.

Vise (J) is especially made to hold sheet metal and other thin materials. It has small, smooth jaws (H) and a swivel base.

Vise (K) is a standard drill press vise. It is portable and is made flat to fit on the adjustable plate of a drill press. The jaws are designed to hold material at a number of different angles for drilling.





HOW TO USE THE VISE

To use any vise, simply rotate handle (B) clockwise or counterclockwise until the desired opening is obtained.

Place your part in the vise and tighten it just enough to hold it in place. If the part being held is soft or brittle, too much pressure will compress, chew up or break it.

CAUTION

Know the type of material being clamped in the vise. Be sure the jaw facings (A) are the type that will not damage the material.

Soft vise jaw-caps (D) are available. They come in pairs and simply slip over the jaw facings for protection. The tabs (C) are then bent around the front and back jaws to hold them in place. A pair of these should be kept around when you want to protect soft material from the teeth on normal jaw facings.

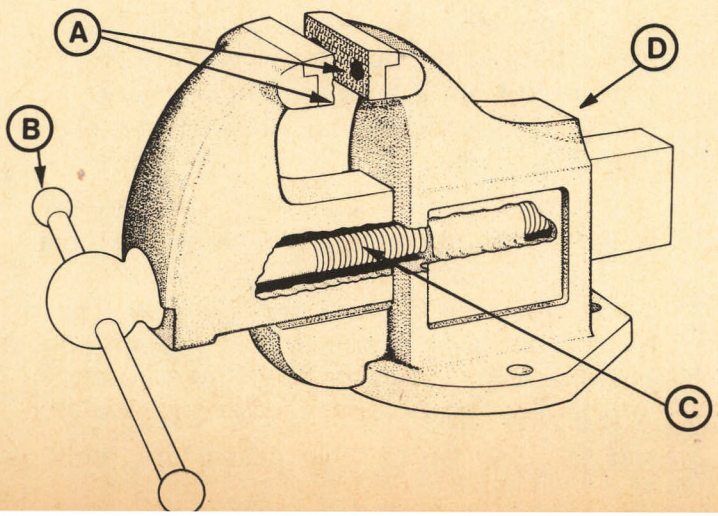
If jaw-caps are not available, use two strips of aluminum, copper, brass or wood to protect the material.

When placing a hard or tough part which is to be hammered or chiseled in a vise, be sure the vise is sufficiently tight to prevent the part from slipping. Place it in the vise in such a position that it can be hammered or chiseled toward the *stationary* (non-moving) jaw (E).

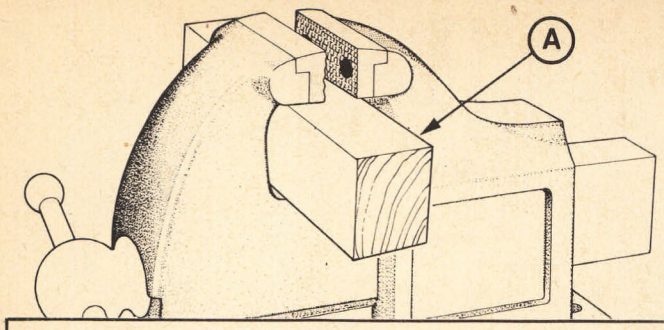
CARE OF VISES

Even though some people disagree with this premise, the vise is a precision tool and should be treated as such.

The following are some tips for proper care of your vise:

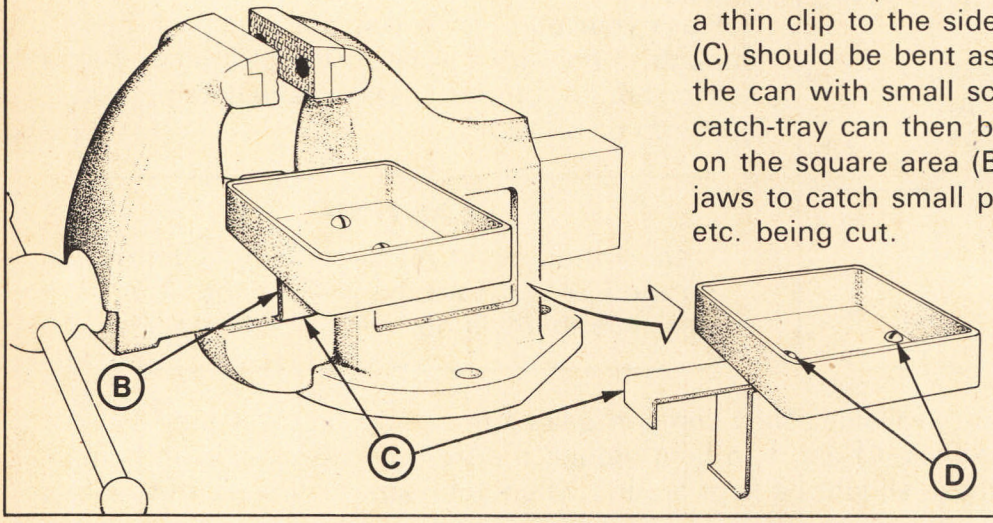


- Never hammer on the vise itself, unless there is an anvil built on the vise for that purpose (usually found in area [D]).
- Keep the screw (C) clean and well oiled by periodically removing it.
- When the jaw facings (A) wear out or lose their gripping power, replace them.
- Never overtighten the vise handle (B) by using an extension bar over the handle ends or by hammering on the handle.

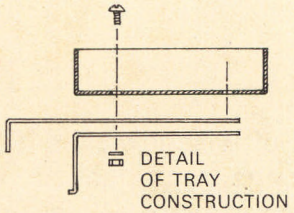


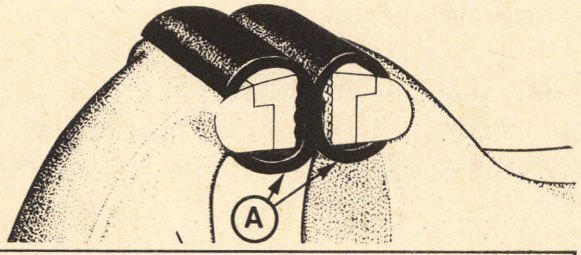
HANDY HINTS

If the material you place in the vise (such as large sheets of material) has a tendency to rotate or drop down in the vise while you're working on it, simply place a block of wood (A) between the vise jaws. The wood must be sized to fit snugly between the jaws and under the material.

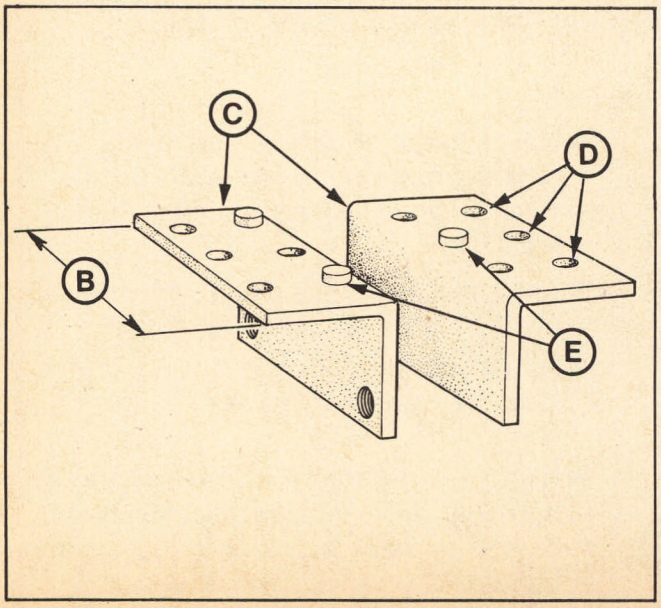


The use of a small catch-tray is a good method of catching the numerous small pieces that fall from the material being cut. This catch-tray can be made out of a shallow can (like a sardine can) by attaching a thin clip to the side of the can. The clip (C) should be bent as shown and attached to the can with small screws or rivets (D). The catch-tray can then be attached to the vise on the square area (B) between the vise jaws to catch small pieces of rod, screws, etc. being cut.





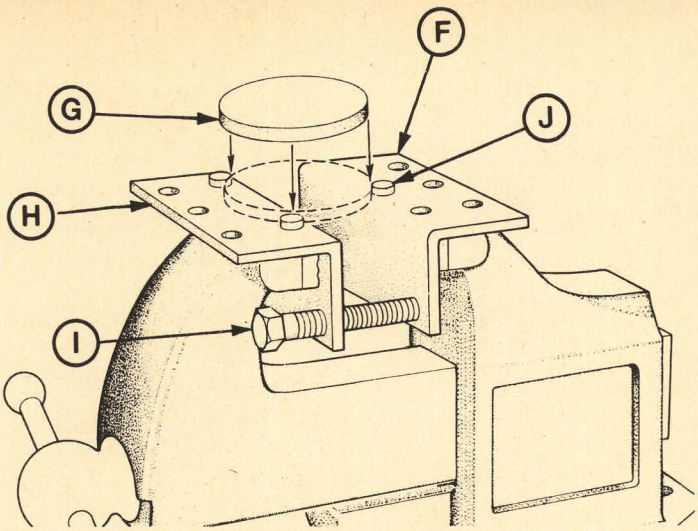
A good tip for protecting soft materials from the jaws of small bench vises is to use cut-off pieces of rubber hose. Just cut off two pieces of old rubber hose (A) approximately the width of the jaw facings. Slit the pieces of hose down the center and slip them over the jaw facings.



Trying to hold thin, flat material (such as washers or thin plates) safely for filing or marking with a scribe is sometimes very difficult with the ordinary vise. With this simple modification, the material will be safely held at the edges and will be supported from the bottom against any pressure applied by a file or other tool on the top surface.

Two pieces of thick angle iron (C) are cut to the width (B) of the jaw facings. Six holes (D) are then drilled into one of the L-sections in each piece of angle iron. The holes must be of a size to accept pins (E) (cut from round bar stock) snugly.

The pins (E) should be cut to a length slightly less than the thickness of the angle

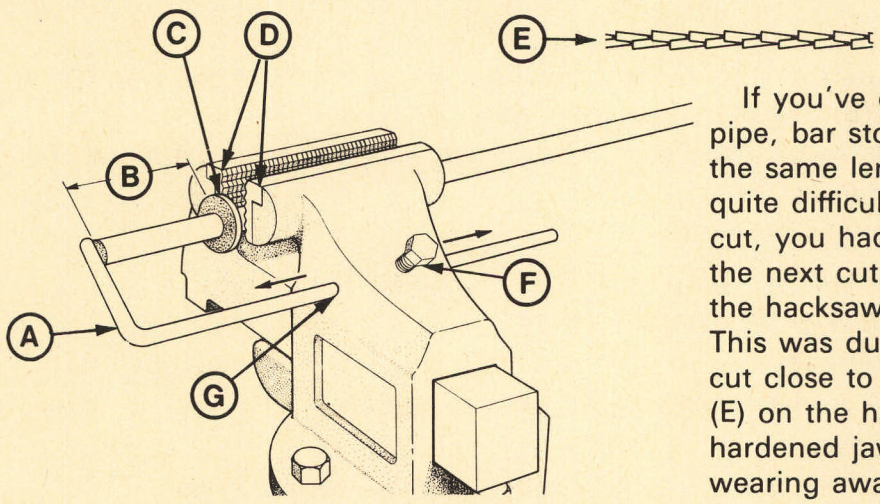


iron, to allow the pin to protrude just less than the thickness of the material being worked on. Usually three pins will securely hold most curved objects.

The pins can then be moved around from hole to hole, allowing you to work on material of various diameters.

When tightening the vise, the forward pressure causes the angle iron to cock forward. To prevent this, drill and tap the piece of angle iron (H), one hole on each side, to accept a screw or bolt (I). This will insure that the top surfaces of the angle iron will remain level when the screw or bolt is properly adjusted.

To properly adjust the screw or bolt, place the thin, flat material (G) between the pins (J) and lightly tighten the vise. Adjust the screw or bolt until the end just touches the opposite piece of angle iron (F). Now tighten the vise the remaining distance.



If you've ever had to cut short sections of pipe, bar stock or other material to exactly the same length, you may have found it quite difficult. With each piece of material cut, you had to re-measure the material for the next cut. Also, you probably found that the hacksaw blade became dull very rapidly. This was due to the fact that as you tried to cut close to the vise, the angle of the teeth (E) on the hacksaw blade rubbed the hardened jaw facings (D) of the vise, thus wearing away the blade tooth angle.

With the following modification, you can eliminate the need to re-measure before each cut as well as save your hacksaw blade from dulling.

First, to prevent tooth damage to the hacksaw blade, place a washer (C) on the round stock so that it comes between the saw blade and the vise jaws. The movement of the saw blade will cause the washer to revolve so that the saw teeth roll on the soft washer face, thus remaining undamaged.

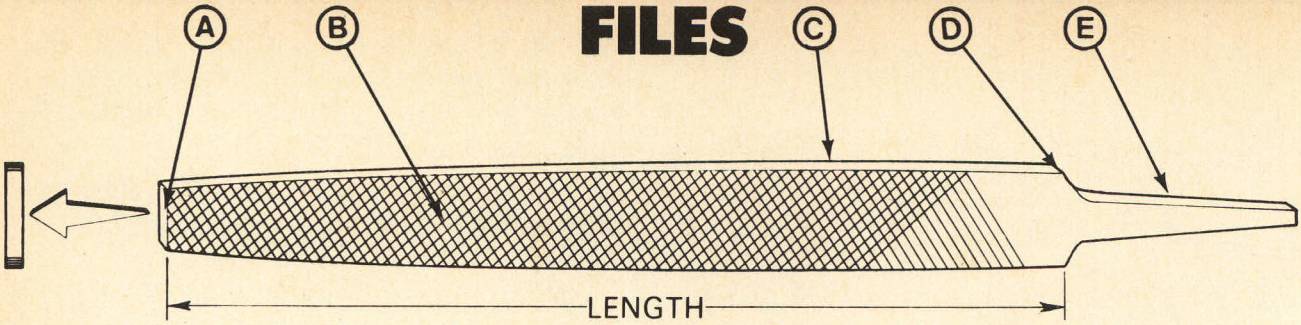
Second, to insure an identical cut length each time without re-measuring, drill a hole (G) through the fixed jaw of the vise. Choose a piece of round bar stock (A) that will fit the hole snugly and bend the end to 90°. Next, drill and tap a hole at the rear of the fixed jaw to accept a bolt (F). This will act as the locking device for the bar stock.

Example: Your task is to cut fine pieces of material 6 inches long. Proceed as follows:

- Measure the bar stock to obtain an extension of 6 inches (B) plus the thickness of the washer.
- Position the bar stock (A) at 45° and tighten the bolt (F). There should be no movement of the bar stock now.
- Place the material to be cut in the vise until it just touches the 90° bend of the bar stock. Be sure the washer (C) is in place. Tighten the vise.

Each time a piece of material is cut off, loosen the vise and move the material over until it touches the 90° bend again. You're then ready for another cut.

FILES



Of all metalworking tools, the file is the most widely used. There are more than 3,000 different kinds, sizes and cuts of files available to the mechanic today. We will not attempt to cover all of them, only the ones used most today.

A file consists of the following parts:

1. Tang (E), the smooth, pointed end where the handle fits.
2. Heel (D).
3. Edge (C). Some have teeth and some do not.
4. Face (B), the area where the teeth are cut.
5. Point (A).

The size of the file is not measured in total length, but from the point (A) to the heel (D) only. Teeth are cut into the faces (B) and sometimes the edges (C) of the file body.

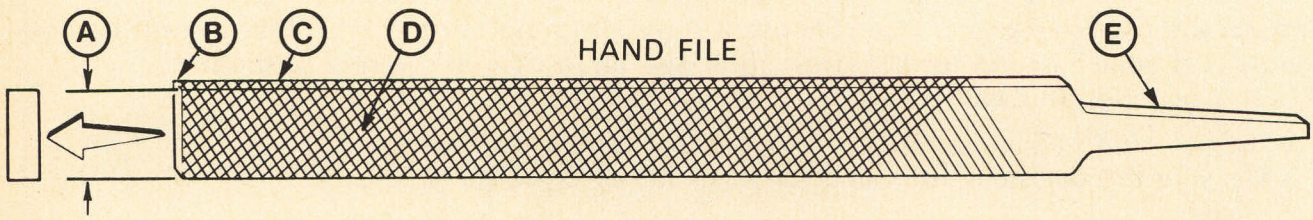
There are different kinds of files to give the best results with different types of metal. For best results when using a file, remember:

- Select the right file for the work to be done.
- Hold the file in the correct position.
- Use the right stroke on the material for accurate results.

The file has the following general uses:

- To remove extra material (body and fender work or ignition points).
- To fit material together more accurately.
- To correct errors resulting from machine tools (threads of screws and bolts, etc.).
- To file a flat surface.
- To file an edge, such as on sheet metal.
- To file a notch, slot or square or round hole.

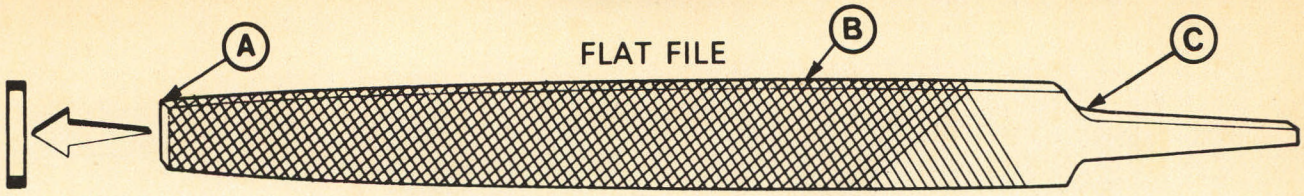
All files are classified in two ways, by their shape and by the type of cutting edges on their faces. Let's look at them first by shape.



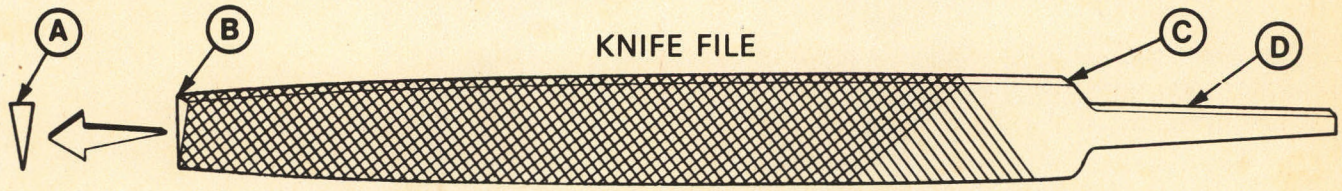
SHAPE

The hand file (E) is one of the most common files in use today. It is used not for any specific job, but for most general filing jobs. The width (A) of this file is usually maintained throughout its length and does not taper at the point (B), as some files do.

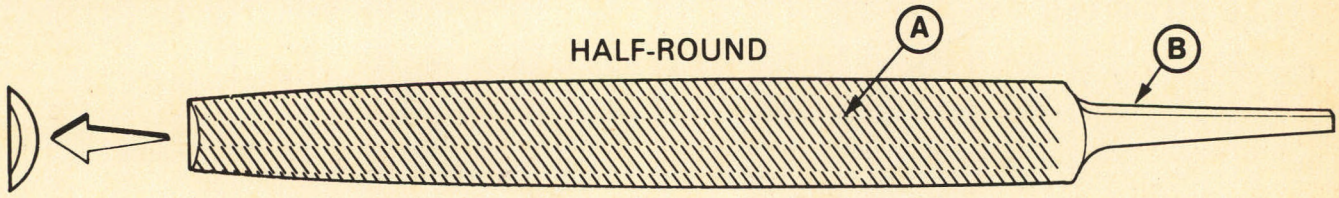
Teeth are cut on both faces (D) and usually only one edge (C). The edge that has no teeth is called the "safe edge." Hand files are usually preferred for filing on flat surfaces.



Notice how the flat file (C) tapers at the point (A), unlike the hand file above. Generally the flat file has teeth on both edges (B). Flat files are also used for general-purpose filing.

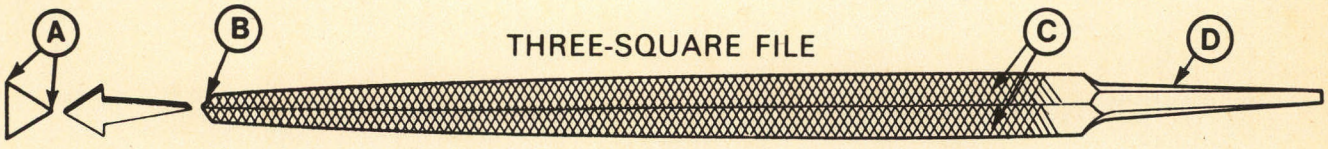


The knife file (D) gets its name from the fact that it resembles the blade of a knife. The taper (A) is toward one edge and runs the length of the file, from the heel (C) to the point (B), with teeth cut on all surfaces. Files of this type are used primarily to file at odd angles, as in the repair of damaged threads on studs, bolts or screws.

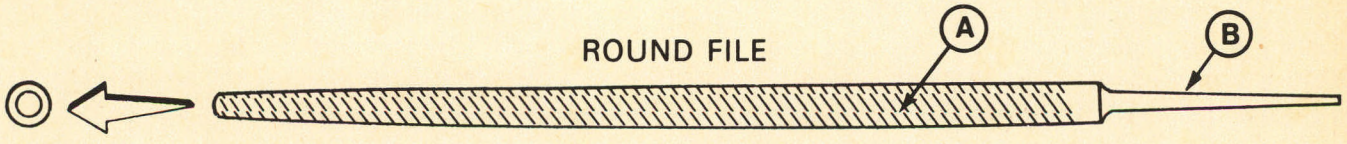


The half-round file (B), as its name indicates, is a file with one side curved, the other side flat and teeth cut on both faces (A).

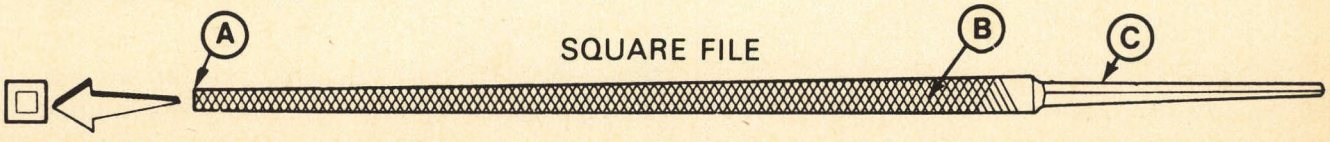
This is a general-purpose file, but it is especially useful when the surface to be filed is curved.



The three-square file (D), also known as the three-cornered file, is used to clean out corners of a square shape or to file at odd angles. The file is tapered its full length to the point (B). All faces (C) have teeth, and the corners (A) between the faces have been left sharp for more cutting area.



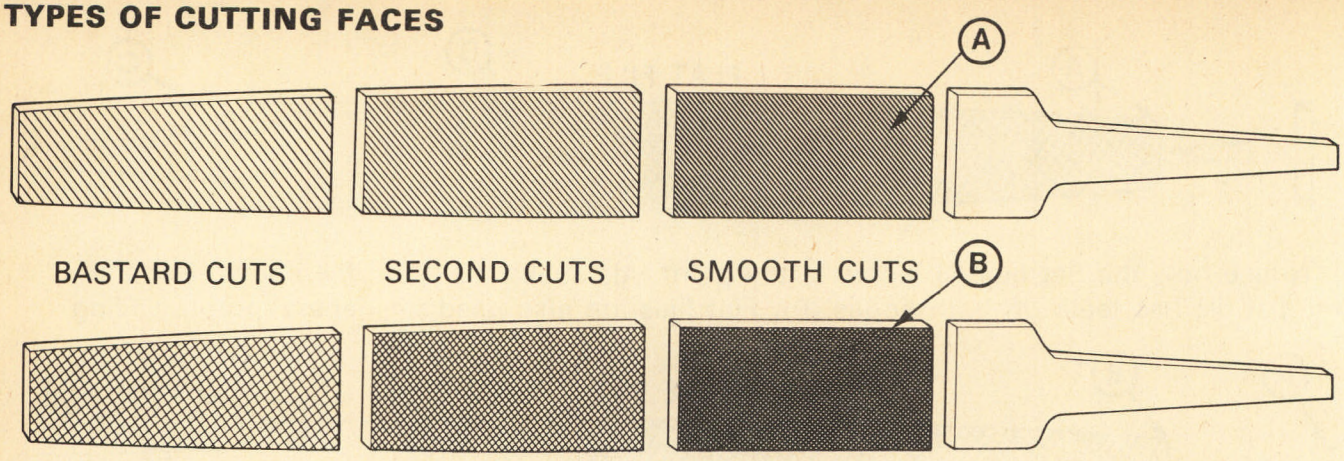
The round file (B), also known as the rat-tail file, is tapered throughout its length, with teeth (A) covering the full diameter. This file is used primarily for enlarging circular openings or filing curved surfaces.



The square file (C) sometimes tapers toward the point (A) but is also available fully square throughout its entire length. Teeth are cut on all four faces (B). The file is used principally for enlarging or finishing holes of a square or rectangular shape and for filing slots and keyways.

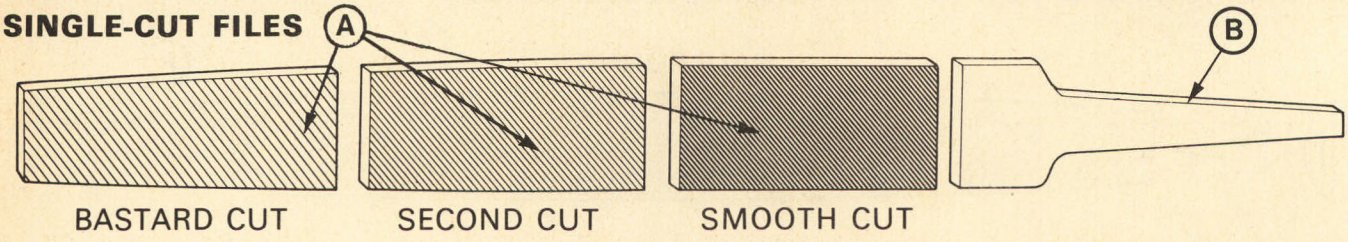
FILES

TYPES OF CUTTING FACES



File cuts are classified into two types, single-cut (A) and double-cut (B). As you can see, the type of cut stems from the arrangement of the teeth. The bastard cuts, second cuts and smooth cuts are perhaps the most widely used for general, all-around filing. Note how the tooth spacing varies with the three grades of cuts shown.

SINGLE-CUT FILES



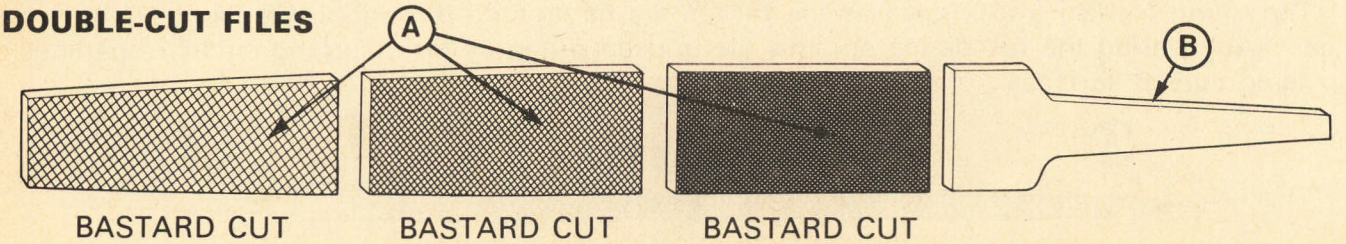
The single-cut file (B) has *one* unbroken course of teeth (A) running across the face of the file. These are easily identifiable by the degree of smoothness of their cut.

Single-cut files are available in six different grades:

- Rough cut
- Coarse cut
- Bastard cut
- Second cut
- Smooth cut
- Dead-smooth cut

The only difference among the grades is the spacing between the teeth. Naturally, the rough-cut file has the greatest space between the teeth. As the cut becomes smoother, the spacing decreases. Remember, though, the spacing applies to the overall size of the file. Example: A *large* bastard-cut file has more space between the teeth and thus larger teeth than a *small* bastard-cut file has, even though both files are bastard-cut files. This applies to all cuts of files. The single-cut file is used when a smooth finish is desired.

DOUBLE-CUT FILES



The double-cut file (B) has *two* broken courses of teeth (A) crossing each other, one course finer than the other.

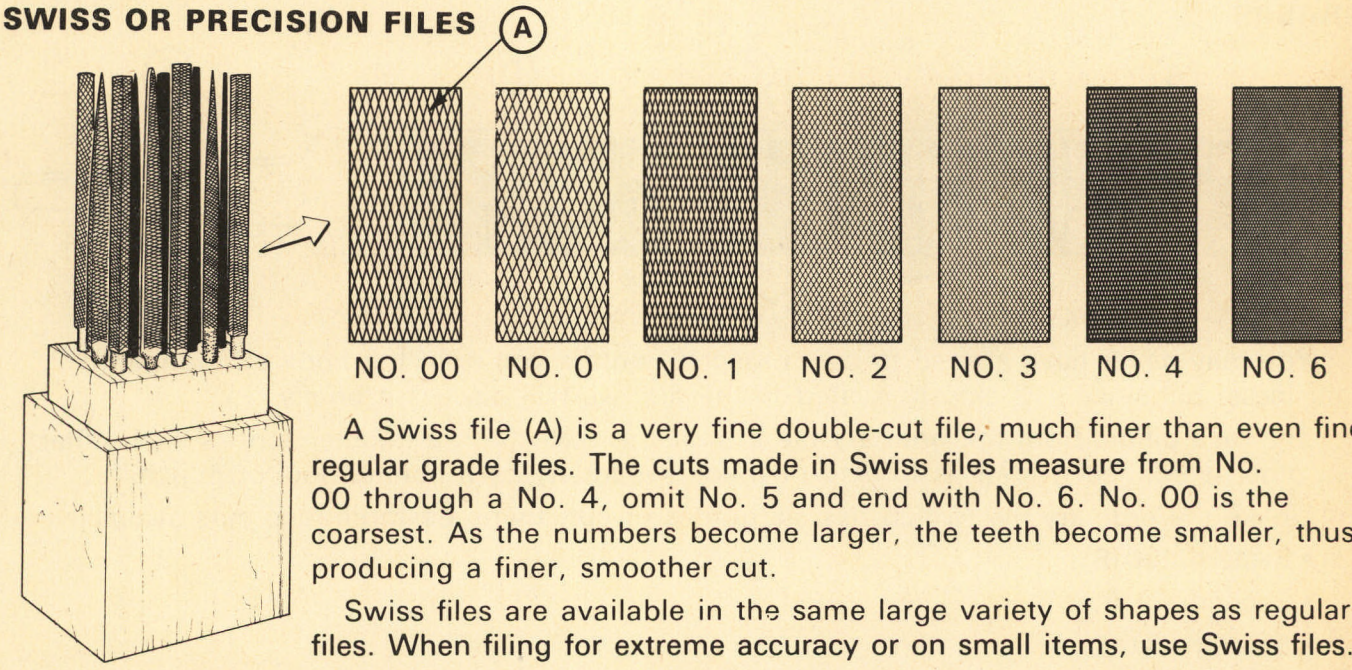
Double-cut files are also available in six different grades:

- Rough cut
- Coarse cut
- Bastard cut
- Second cut
- Smooth cut
- Dead-smooth cut

The spacing between the teeth, as discussed under single-cut files, applies also to double-cut files.

The double-cut file is used for rough, fast metal cutting or where large amounts of material must be filed off.

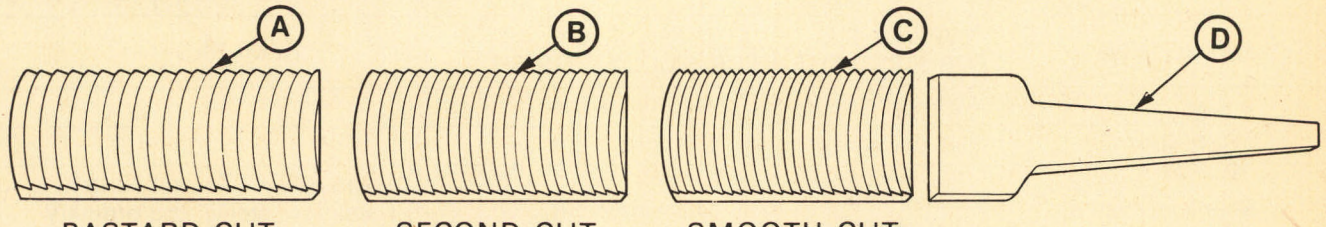
SWISS OR PRECISION FILES



A Swiss file (A) is a very fine double-cut file, much finer than even fine regular grade files. The cuts made in Swiss files measure from No. 00 through a No. 4, omit No. 5 and end with No. 6. No. 00 is the coarsest. As the numbers become larger, the teeth become smaller, thus producing a finer, smoother cut.

Swiss files are available in the same large variety of shapes as regular files. When filing for extreme accuracy or on small items, use Swiss files.

CIRCULAR-CUT FILES



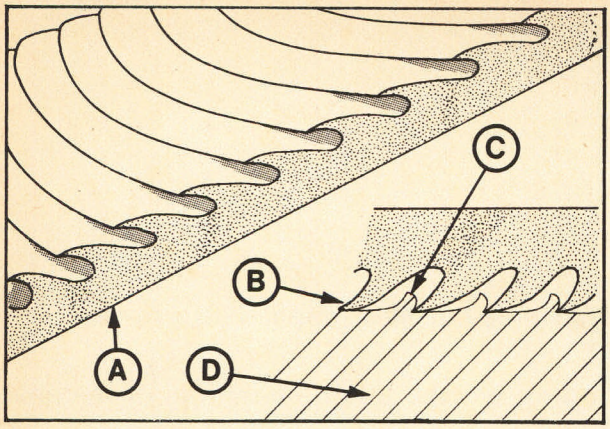
The circular-cut file (D), also known as the curved-tooth or vixen file, is used to file soft metals such as lead, aluminum, etc. It removes soft metal very quickly and will produce a smooth surface after each filing stroke.

CAUTION

Because of its coarse teeth, do not use the circular-cut file on small or narrow surfaces or damage to the material will result.

This file is available in bastard cut (A), second cut (B) and smooth-cut (C) grades.

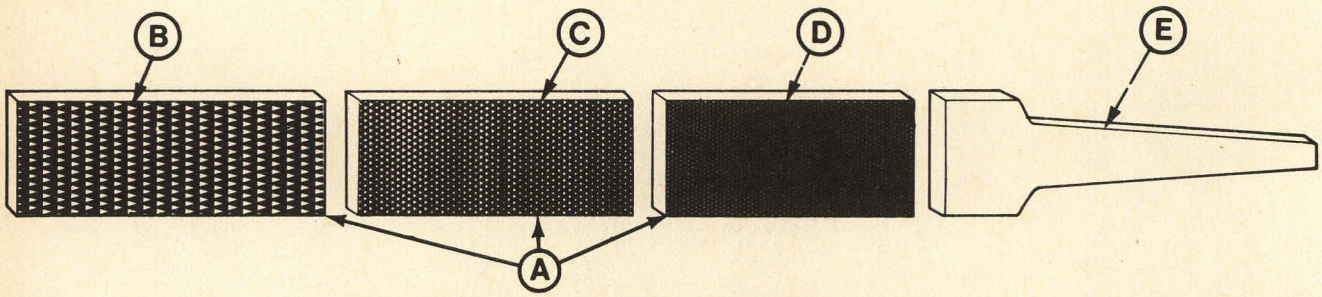
FILES



The bastard circular-cut file (A) has approximately 10 teeth (B) per inch. This gives good clearance for the filings (C) to build up and drop out. Therefore the space between the file teeth doesn't clog up and cause the file to bend. A clogged file causes vibration and chatter across the material being filed (D), damaging it.

Remember, we have only discussed a few of the different sizes and shapes of files available. There are thousands of different sizes and shapes manufactured. Be sure to specify length, shape and cut when purchasing any file.

RASPS



You may never have a need to use a rasp (E) unless you're in the body and fender business, but since it is closely related to the file, we will discuss it briefly.

The rasp differs from the ordinary file in that the teeth (A) are independent of each other. In other words, each tooth is formed or made separately by a pointed tool or punch.

Unlike the ordinary file, which has six grades of cut, there are three rasp cuts available:

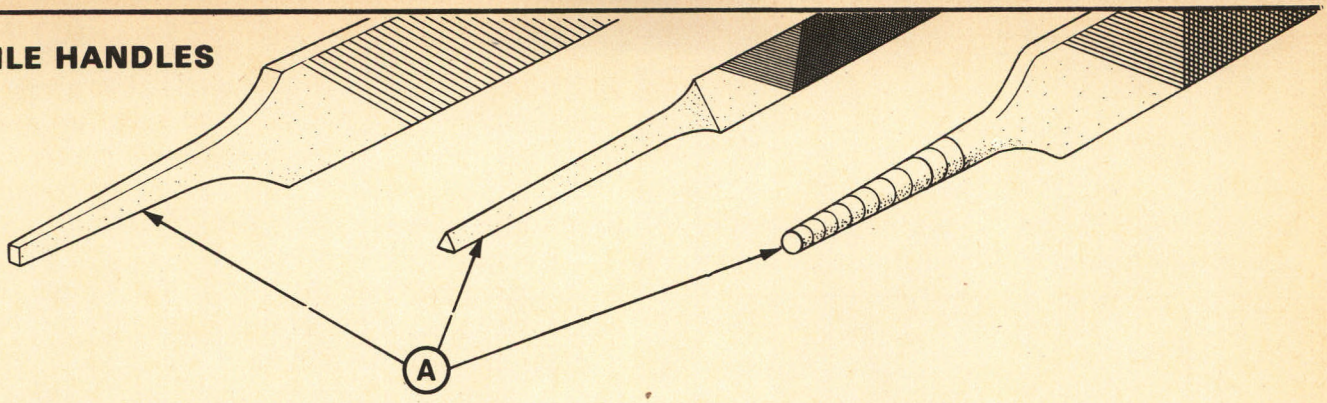
- Bastard cut (B)
- Second cut (C)
- Smooth cut (D)

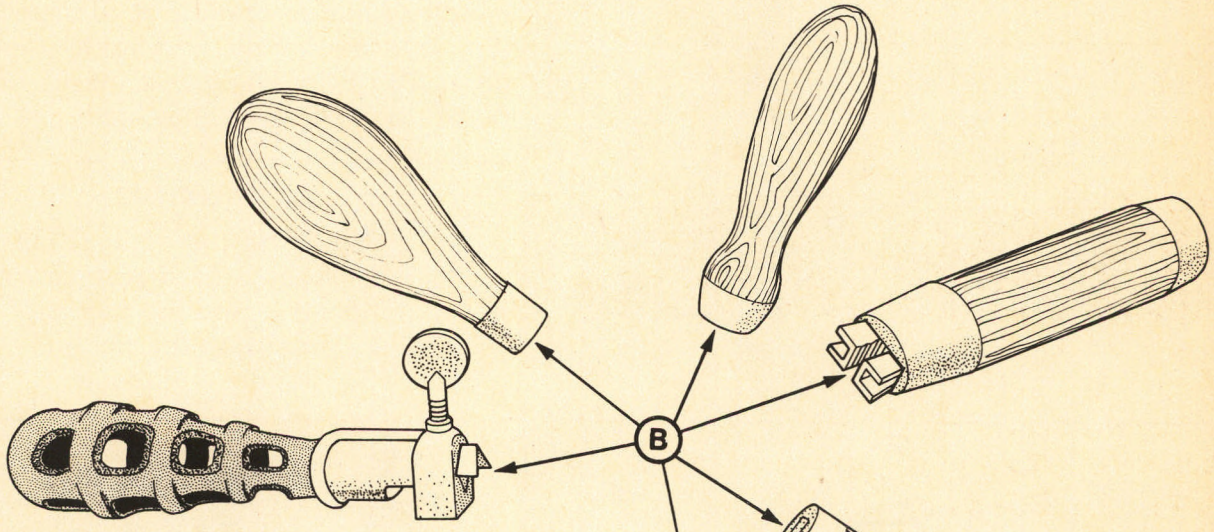
The rasp is used for heavy, rough work, where large amounts of material must be removed with just a few strokes.

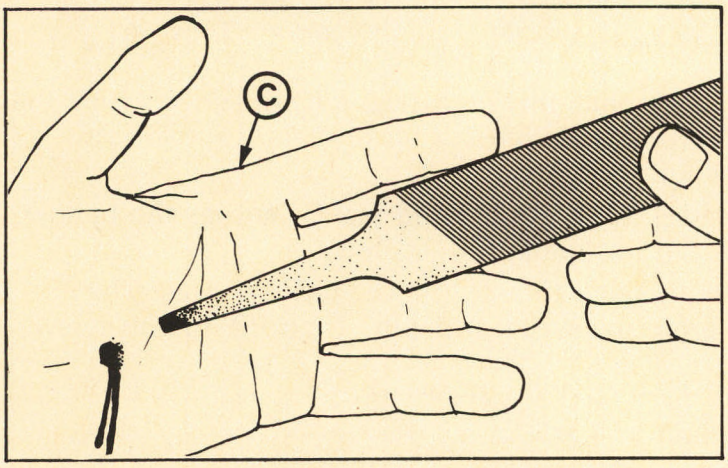
METAL TYPE	TYPE OF FILE FOR FIRST CUT	TYPE OF FILE FOR SMOOTH FINISH	REMARKS
Cast iron	Flat double-cut	Flat single-cut	
Soft steel	Flat double-cut	Flat single-cut	
Stainless steel	Special stainless steel file	Flat single-cut	Due to chrome/nickel content of stainless steels, the ordinary file dulls quickly.
Brass	Special brass file	Flat single-cut	Brass is soft but tough. Requires EXTRA SHARP teeth for cutting. File has a special angle on teeth.
Bronze	Use special brass file	Flat single-cut	The standard file will cut these materials but has a tendency to clog very easily. These special files have a different tooth pattern that slows down or even prevents clogging of the file. When purchasing a file to cut these materials, ask for a special file.
Copper	Use special brass file	Flat single-cut	
Aluminum	Special aluminum file	Flat single-cut	
Lead	Special lead file	Flat single-cut	

This table will show you which file to use with different types of metals.

FILE HANDLES







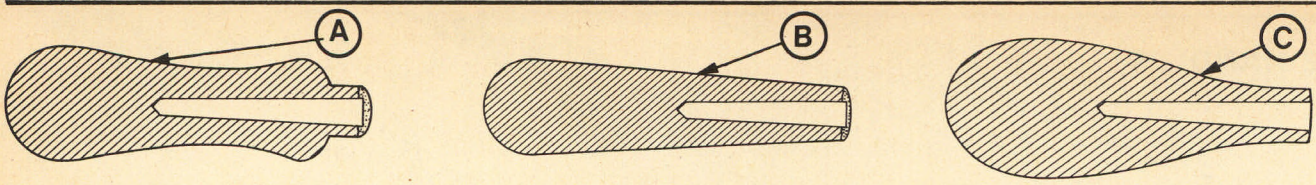
As you can see, there are many kinds of file handles to fit almost any file made. Files are sold without handles, so the first step in using a file is to fit it with the proper handle.

Always select a handle to properly fit the file—not too large nor too small for the file tang (A), (handle end). This is important. The urge to use a file without a handle is great, but use one anyway.

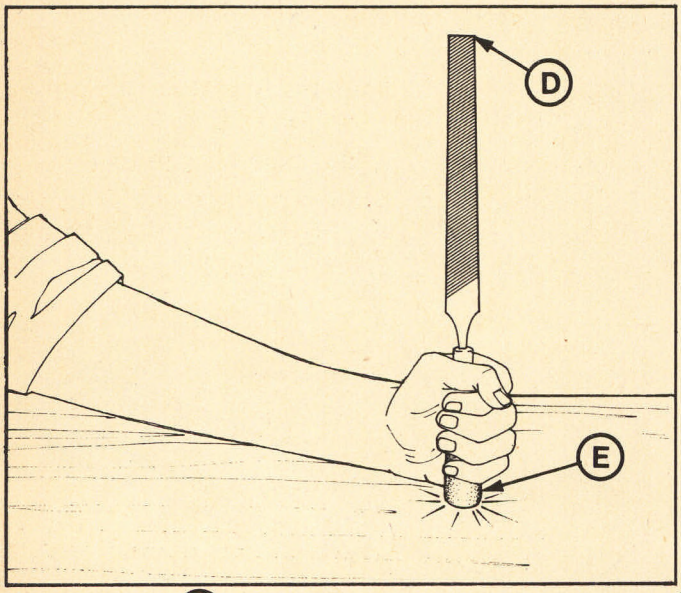
There are two excellent reasons for using a file handle on all files. The first and most important is safety to the user. The tang of a file is usually pointed. If you meet an obstruction while filing and the file stops suddenly, your hand (C) could be severely punctured.

Secondly, the work you're doing can be done more accurately and faster if a good file handle with a strong ferrule (B) is used.

File handles range from very cheap ones made of soft pine with a cheap ferrule to very expensive hardwood handles with self-cutting teeth to hold the handle firmly on the file.



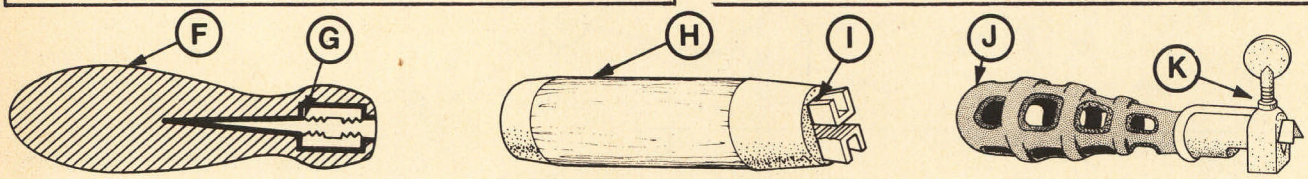
Handles (A), (B) and (C) are cheap handles. These handles already have the hole to accept the file tang drilled into the handle.



To install handles (A), (B) or (C), simply place the tang of the file into the hole of the handle and tap the handle (E) on a work bench, edge of a vise or other hard surface until the tang is firmly seated (tight) in the handle. Another method is to install the file tang into the handle and lightly tap the point (D) of the file with a plastic or rawhide mallet until the tang is seated.

CAUTION

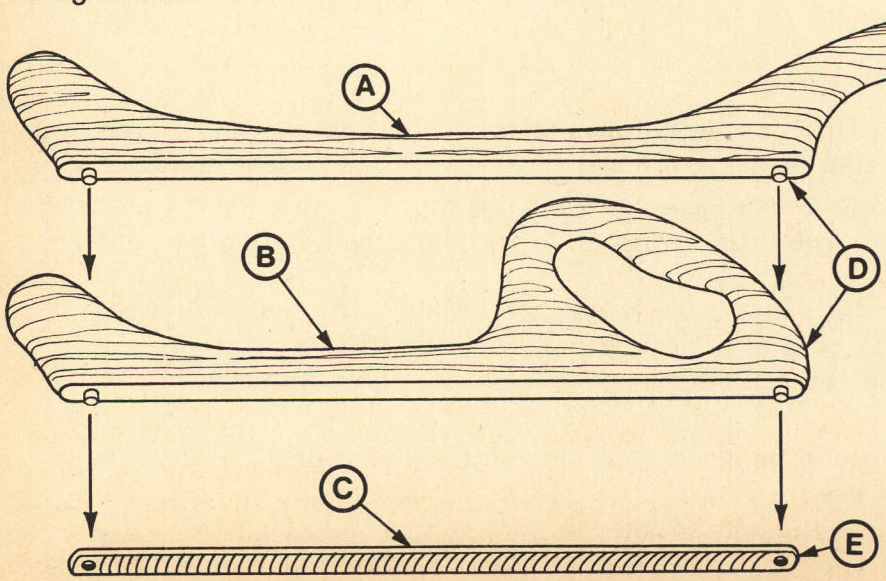
Never hit the point (D) of a file on a hard surface to drive it into the handle. Damage to the file and handle will result.



Handle (F) is the best. This handle has a hard metal-threaded sleeve (G) inserted inside the ferrule. As the handle is screwed onto the tang, threads are cut on the tang to hold it in place. This type of handle provides a very secure connection.

Handle (H) is also a good one. The threaded jaws (I) are tapered inside, and as the handle is pressed into the tang of the file, the teeth dig in, holding it securely.

Handle (J) is a metal handle which can be adjusted to accept most types of files. The thumb-screw (K) is loosened and the file inserted to its fullest depth. Then the thumb-screw is tightened.



Other types of file handles are the saw handle type of file holder (B) and the straight type of file holder (A). These handles are made to hold the circular-cut file (C), which is used for body and fender work. As you can see, the holes (E) in the file fit over pins (D) on the bottom of the handle to secure the handle for heavy cutting jobs.

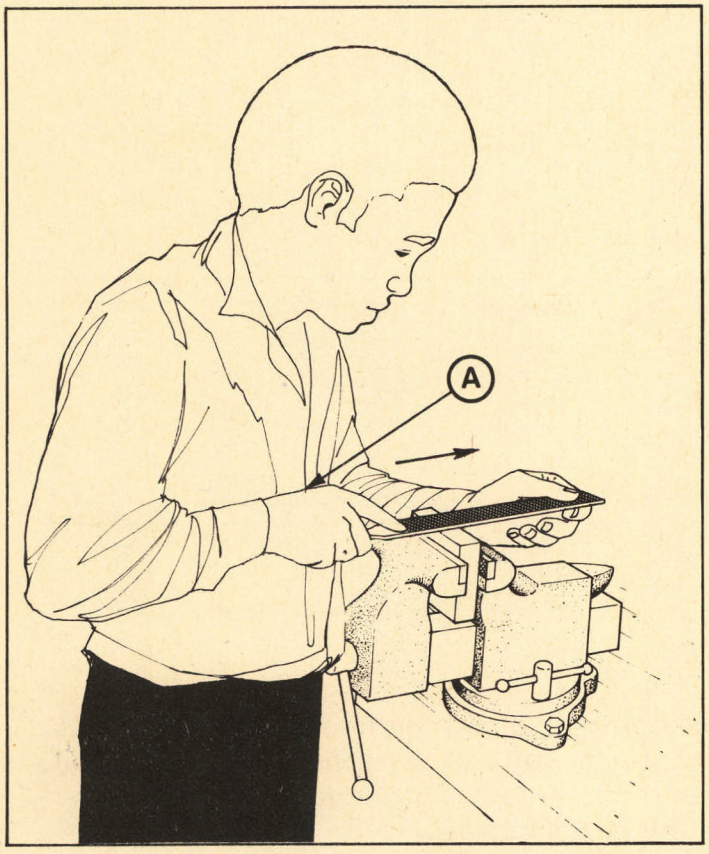
HOW TO USE FILES

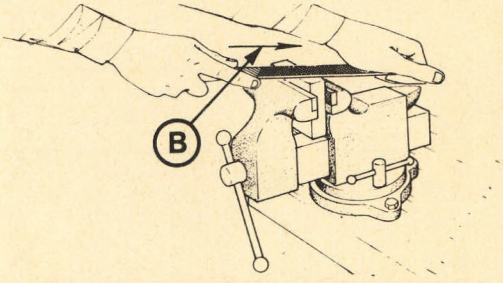
Now that we have learned something about file shapes, cuts and handles, let's learn how to use them properly.

The best advice for the beginner in filing is to take your time, check your work frequently and do the job correctly. Some very common mistakes made by beginners are:

- Rocking the file from left to right as the material is being filed, creating a curved rather than a flat surface.
- Bearing down too hard in the middle of long cuts, thus creating a dip in the middle of the material.
- Filing for too long a period without checking the material, thus failing to detect the removal of too much material or incorrect filing methods.

With practice, you will soon "feel" the work through the file. Just by feel you can tell how much material is being removed, whether you're filing at too great an angle, coming too close to an edge or even if there is any unevenness in the surface of the material. Remember, a file is not a crude tool. In the hands of an expert, it becomes a precision tool.





Most filing jobs are done in a vise, with the vise adjusted to the proper height. For general use, the vise should be positioned at elbow height; if much filing is to be done, the vise should be positioned lower. Of course, if the work is delicate or very small, the vise should be positioned nearer to eye level.

CAUTION

Be sure to protect the material being filed from the vise jaws by placing pieces of wood, plastic or soft metal between the vise jaws and the material.

It is important that the body be in the correct position for filing so that muscles can move freely. If you are right-handed, place your left foot just in front of your right foot, pointing forward. When filing, your body should lean forward during part of the forward stroke, then return to the original position at the end of the stroke.

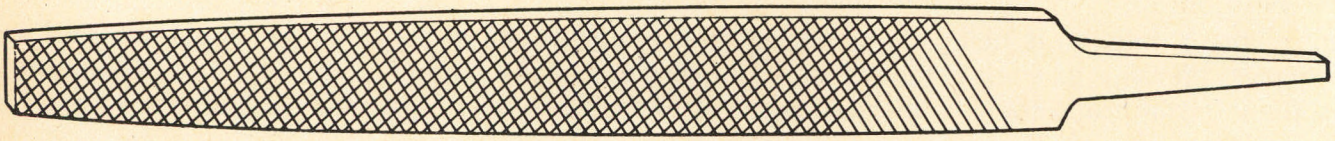
When moving the file across any work, hold the file as shown in illustration (A) and move it straight ahead or at just a slight angle (B). Notice that the handle is held so that the handle end fits into the palm of the hand, with the thumb lying lengthwise along the top, left-hand side of the handle.

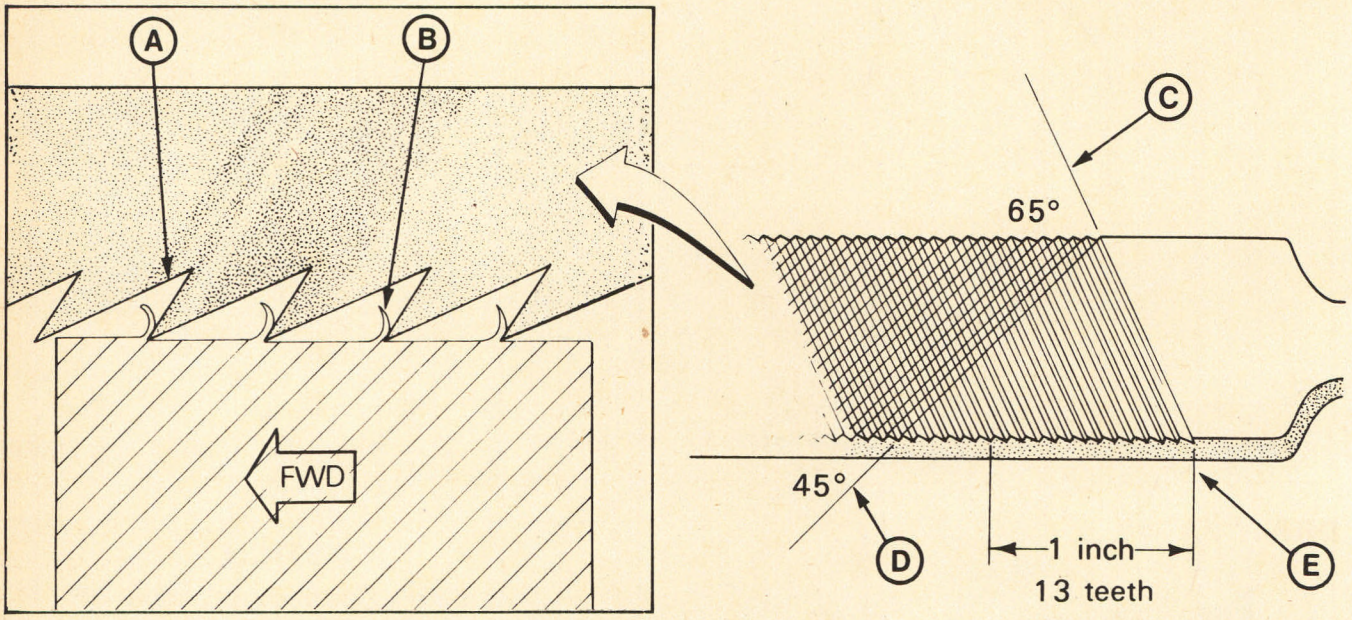
The point of the file is held by the thumb and first two fingers of the other hand. For heavy filing strokes, the underside of the thumb should press down on the file's upper face and should be approximately in line with the handle. For finer, lighter strokes, the thumb can be placed more at a right angle to the file. As you become more experienced with the file, you will get more accustomed to holding it properly.

When filing, do not exert too much pressure on the file and keep the file fully engaged with the material to the end of the filing stroke.

CAUTION

When filing the edge of thin metal in a vise, do not allow the material to extend too far beyond the jaws of the vise or the material will vibrate, causing damage.





The teeth (A) of a file are made so they will cut only during the forward stroke. Always raise the file slightly on the return stroke (except with soft metals such as aluminum, brass, copper, etc.). This allows chips of the cut material to drop out of the teeth and prevents dulling of the teeth caused by the wearing away of their backs.

If you are filing a soft material such as aluminum, the correct method is to exert a slight downward pressure when you draw back the file along the metal. This method automatically cleans any cuttings out of the teeth of the file.

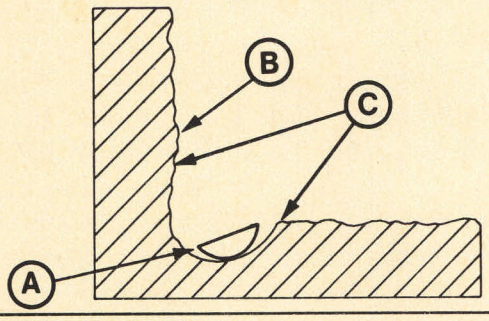
Later we will discuss the care of your file in more detail, but while we are on the subject of filing soft material, just a few words of caution.

To prevent your file from clogging (a clogged file scratches the surface of the material being cut and prevents some of the file teeth from doing their job), tap the handle of the file frequently to remove excess chips. Another method is to coat the file teeth with blackboard chalk, candle wax or turpentine. By first coating the file teeth, the areas (B) between the teeth are filled to capacity and do not allow chips to collect or remain.

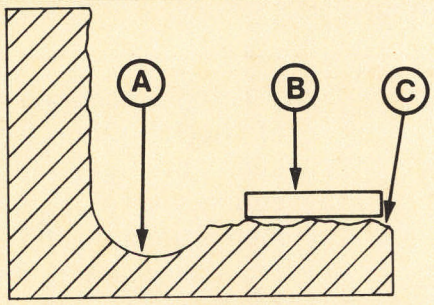
There are *special* files called aluminum files made for cutting soft materials. These files are double-cut on both sides with rows of different-size teeth set at two different angles, 65° (C) and 45° (D). There are approximately 13 teeth per inch (E) on this file.

FILING SURFACES OF DIFFERENT SHAPES

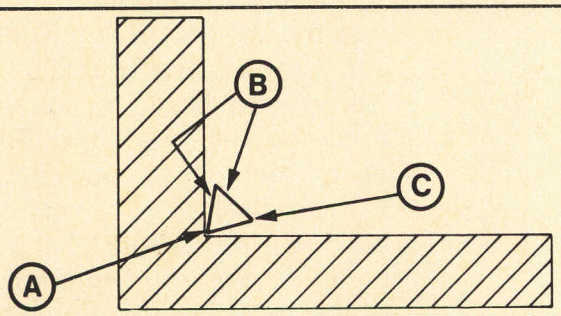
The following three files and three different material surface angles are the most fundamental ones that you will encounter when using a file. All other file shapes can *basically* be used on similar material angles by using good judgment.



When filing a curved surface (B) on any material, use the ordinary half-round file (A). The file should be moved around the entire arc (C) of the curved surface with each forward stroke of the file.

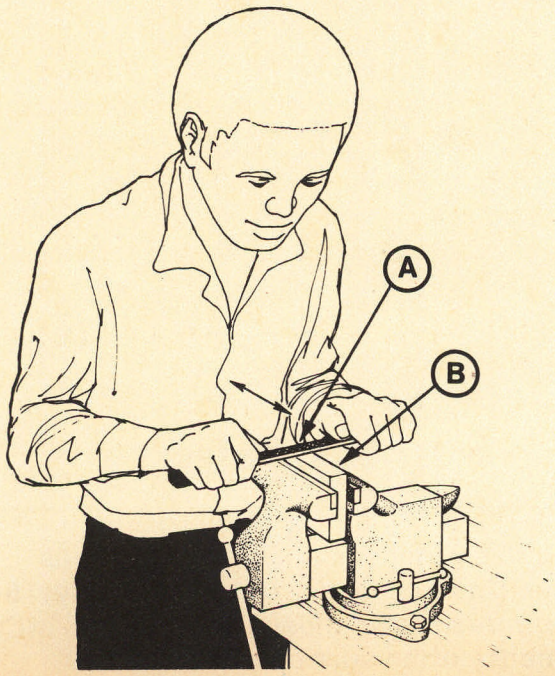


If repairing a flat surface (C) that is to join a curved surface (A), it is best to use the half-round file and file the curved surface first. Then, using the flat file (B), file down the flat surface to meet the curved surface. Be careful not to let the flat file bite too deeply or damage to the curved surface will result.



The three-square file (C) is used to finish a square corner (A) or to file at odd angles. Care must be taken in using the square-shaped file. Do not let the sides (B) of the file come in contact with the sides or bottom of the material being cut; damage to the material will result.

DRAW FILING



Draw-filing is used when you wish a smooth surface and where small amounts of material are to be removed at a time. Only the single-cut file should be used for this purpose, never the double-cut file.

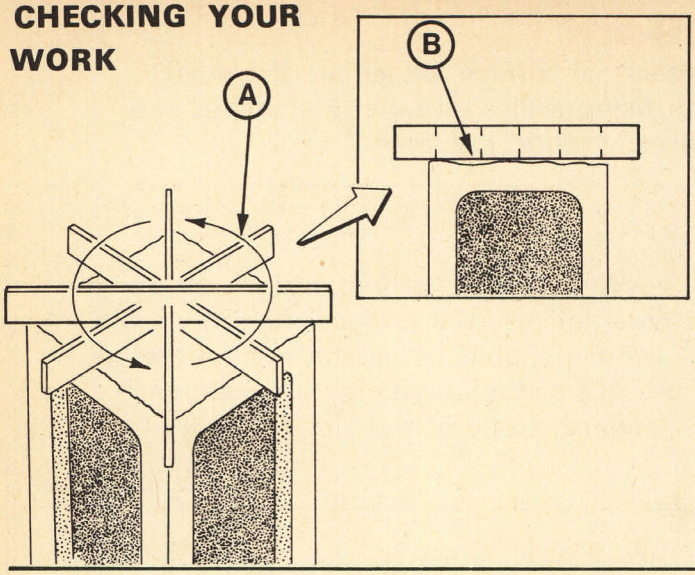
The smoothest surface is obtained from the file cuts which are closest together and create a shearing or shaving action.

Hold the file (A) in both hands with your thumbs approximately ½ to 1½ inches from each side of the material (B) being cut. Then either push or pull the file straight across the surface.

Again, raise the file slightly on the back stroke, as with ordinary filing, except in the case of such soft metals as aluminum, brass, copper or lead (described earlier in this section).

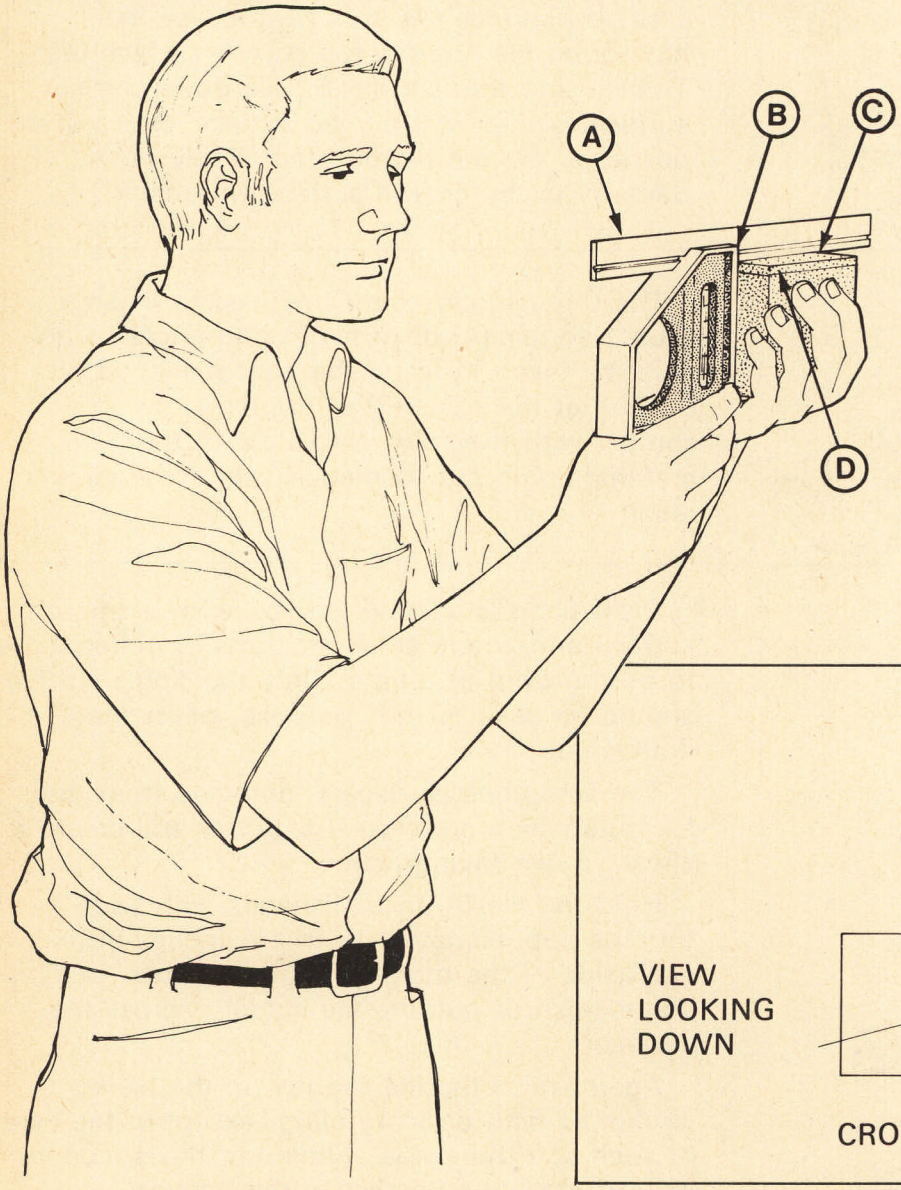
In using different cuts of files, the angle at which the file is moved across the material will vary slightly. Trial filing angles will prove which is best for the type of material being cut.

CHECKING YOUR WORK

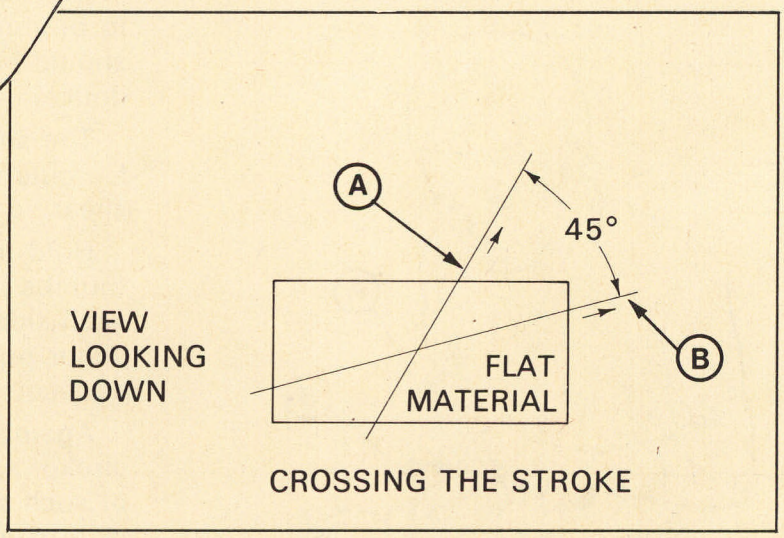


When filing a piece of material, always stop and check your work for even cutting and squareness after so many filing strokes. If you are filing incorrectly or at the wrong angle, you will discover it before the material has been ruined.

The simplest method of checking your work is to place a steel rule (A) across the flat surface being filed. There should be no clearance between the surface (B) of the material and the steel rule if the filing has been done correctly. Move the rule around to different locations on the material and check again for even cutting and squareness.

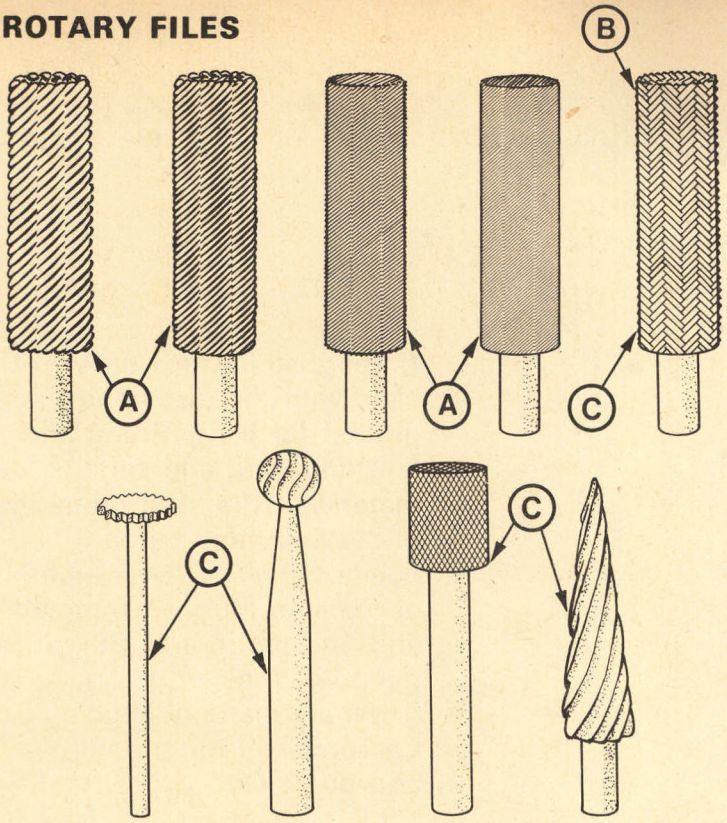


A more accurate method of checking your work for even cutting is with a steel square (A). (For step-by-step instructions on the use of the steel square, see "Petersen's Guide to Automotive Measuring Tools and How to Use Them.") Hold the body of the square firmly against one edge (B) of the material (D) and check that no clearance is visible between the bottom of the blade (C) and the top edge of the material. If clearance is visible, your filing methods are incorrect.



Another method for checking the filing accuracy of a flat surface is a method known as crossing the stroke. The angle of the normal filing stroke (A) is changed to approximately 45° (B). Changing the filing angle from the previous stroke immediately shows the presence of any high spots by file mark variations and new shiny areas on the surface of the material.

ROTARY FILES



The speed recommended for the operation of rotary files varies with the diameter of the file head and the material being filed.

To obtain the best performance from a rotary file made of High Carbon or Chrome Steel, follow the information in the table.

WARNING

NEVER USE A ROTARY FILE WITHOUT WEARING SAFETY GLASSES. ALSO, FIRST CHECK THE FILE TO BE SURE IT IS STRAIGHT AND UNDAMAGED. FAILURE TO OBSERVE THESE TWO PRECAUTIONS CAN RESULT IN SEVERE INJURY OR EVEN DEATH.

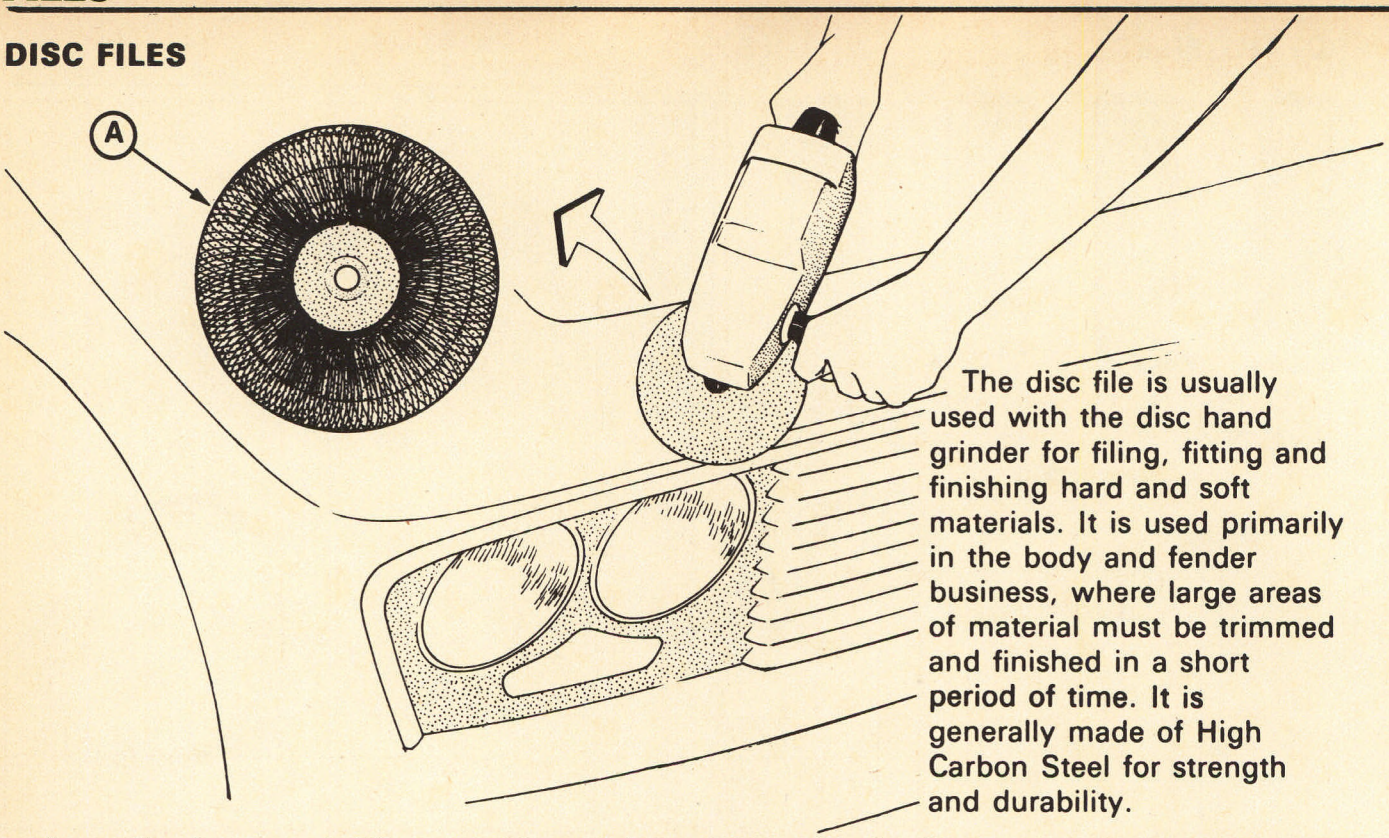
FILE HEAD DIAMETER	TOOL STEEL, CAST IRON	CARBON TOOL STEEL, WELDS, HARD BRONZE, WHITE GOLD	MILD STEEL, BRONZE, HARD BRASS	BRASS, COPPER	ALUMINUM, SOFT METALS, PLASTICS, FIBER, RUBBER	WOOD
INCHES	RPM*	RPM	RPM	RPM	RPM	RPM
1/16	5,000	6,400	7,500	12,000	16,000	24,000
1/8	2,500	3,200	3,750	6,000	8,000	12,000
3/16	1,670	2,150	2,500	4,000	5,400	8,000
1/4	1,250	1,600	1,875	3,000	4,000	6,000
5/16	1,000	1,300	1,500	2,400	3,200	4,800
3/8	835	1,100	1,250	2,000	2,700	4,000
7/16	720	920	1,075	1,900	2,300	3,500
1/2	625	800	1,000	1,500	2,000	3,000
5/8	500	650	750	1,200	1,600	2,400
3/4	420	550	625	1,000	1,400	2,100
7/8	360	475	550	950	1,200	1,800
1	320	450	500	750	1,000	1,500

*Revolutions per minute

Rotary files are used with a drill motor to cut, grind and smooth materials in those hard-to-reach areas at a high rate of speed. Just like the hand file, they are made in many shapes (C), single cut (A) or double cut (B) and in many grades of cut coarseness.

Most high-quality rotary files are made of High Carbon or Chrome Steel to withstand the high speeds and grinding pressures put upon them.

DISC FILES



The disc file is usually used with the disc hand grinder for filing, fitting and finishing hard and soft materials. It is used primarily in the body and fender business, where large areas of material must be trimmed and finished in a short period of time. It is generally made of High Carbon Steel for strength and durability.

These files have teeth (A) on one face only and are made in different grades of coarseness, just like the hand files and the rotary files mentioned earlier.

TYPE OF CUT	TEETH PER INCH	MATERIALS
DOUBLE EXTRA COARSE CUT	7	WOOD
EXTRA COARSE CUT	9	ALUMINUM, LEAD, TIN, ZINC, PLASTICS, FIBER, HORN AND LEATHER
COARSE CUT	12	BRASS, COPPER, BRONZE
MEDIUM CUT	18	STEEL AND CAST IRON
FINE CUT	24	TOOL STEEL
SMOOTH CUT	32	HARD ALLOY STEELS

Disc file cuts are identified as double extra coarse, extra coarse, coarse, medium, fine and smooth, as shown in the table above. Besides various coarsenesses of cut, disc files are made in a spiral (curved) cut and a segmented (divided into segments) cut.

DIAMETER OF DISC	TOOL STEEL, CAST IRON	STEEL	BRONZE	BRASS, COPPER	ALUMINUM, OTHER SOFT METALS	WOOD
	RPM*	RPM	RPM	RPM	RPM	RPM
4″	120	180	250	350	900	1,400
6″	80	120	180	250	600	900
8″	60	90	140	180	450	700
10″	50	60	110	150	380	600
12″	40	60	80	120	300	480
16″	30	45	60	90	220	350

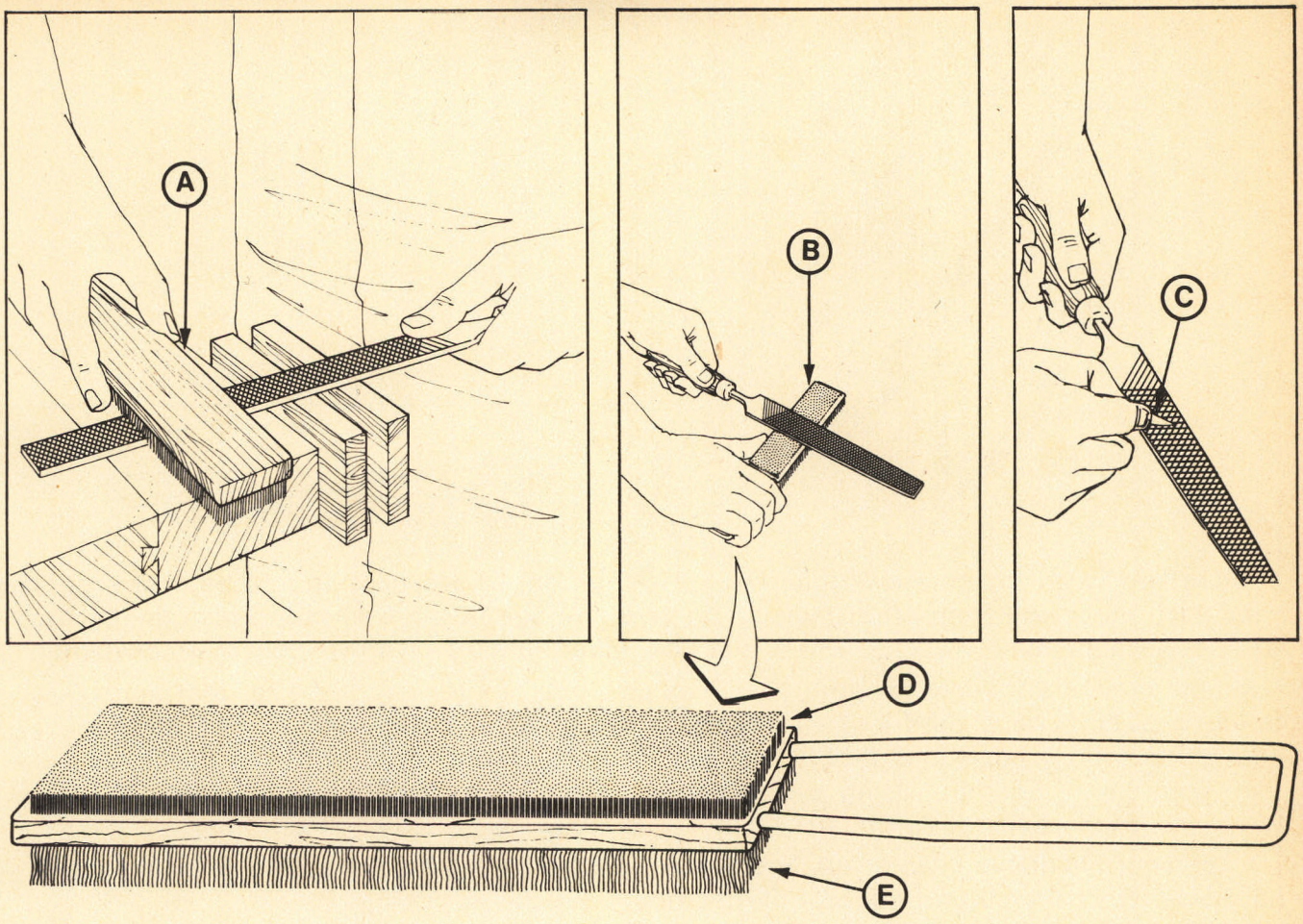
* = REVOLUTIONS PER MINUTE

Spiral-cut files are made with teeth arranged in a spiral formation around the file's face.

Segmented-cut disc files are made by fitting together four or more segments, much as slices of pie can be fitted together to re-form the whole pie. Each of these segments has file teeth cut on its flat surface. A disc file results when these segments are fitted together.

The table above tells the correct speed for filing various materials with a particular size of disc file.

PROPER CARE OF FILES



As particles build up between the teeth of your file, they must be removed to retain the fine cutting edges of the file teeth. If tapping the file handle on a hard surface does not remove the chips, they should be removed by using a file brush (A) or file card (B).

A file card is a brush with bristles (D) on one side and a fine-wire brush (E) on the other. The wire is fine (small) enough to enter a fine-tooth file and *loosen* chips and dirt. Then, turning the brush over, the bristle end is used to finish cleaning the areas between the teeth.

Sometimes when filing soft metals such as aluminum, copper and lead, filings will remain stuck between the teeth after using the file card. If this happens you should use a sharp, pointed piece of soft iron (C) to pick the remaining filings from between the teeth.

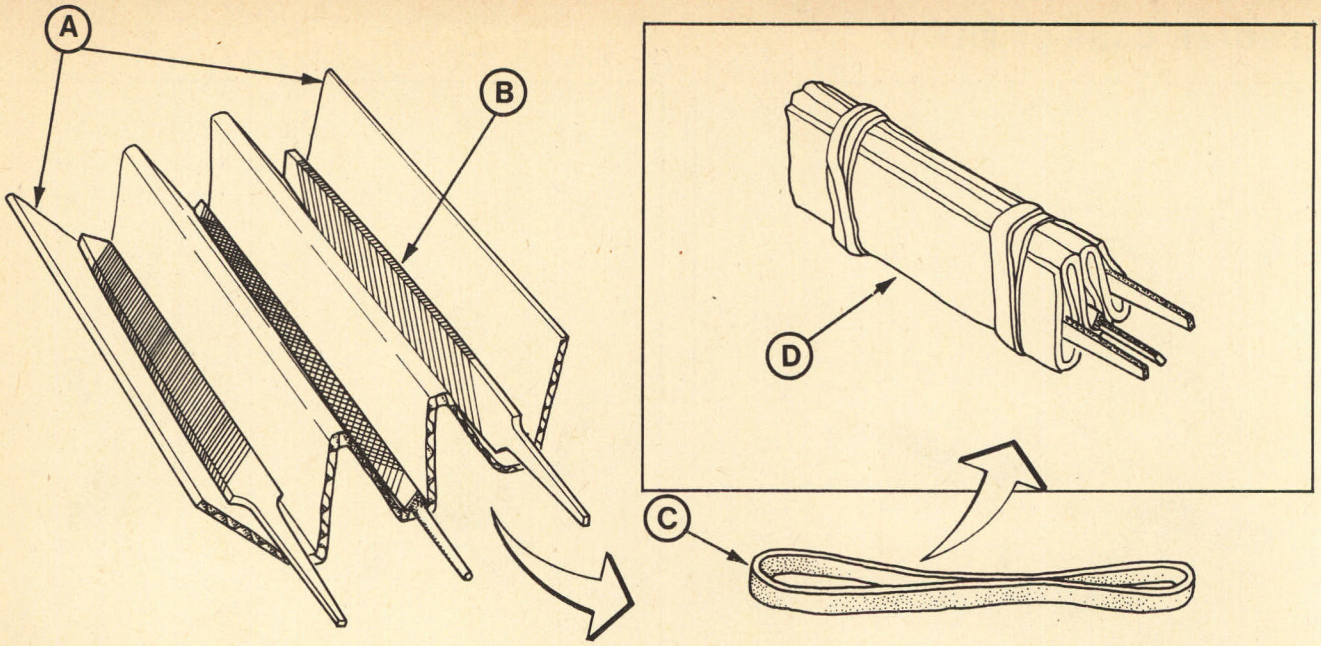
CAUTION

Never use a piece of hardened steel (such as a pointed punch or chisel) to pick file teeth clean. Damage to the teeth can result.

Remember, to prevent your file from clogging when filing any material, perform any of the following:

- Tap the handle of the file on a hard surface frequently.
- Rub blackboard chalk thoroughly on the file teeth before starting to file.
- Apply turpentine to the blade of the file before filing.
- Rub candle wax across the file teeth before filing.
- Frequently brush the file teeth with a good file card.

FILES

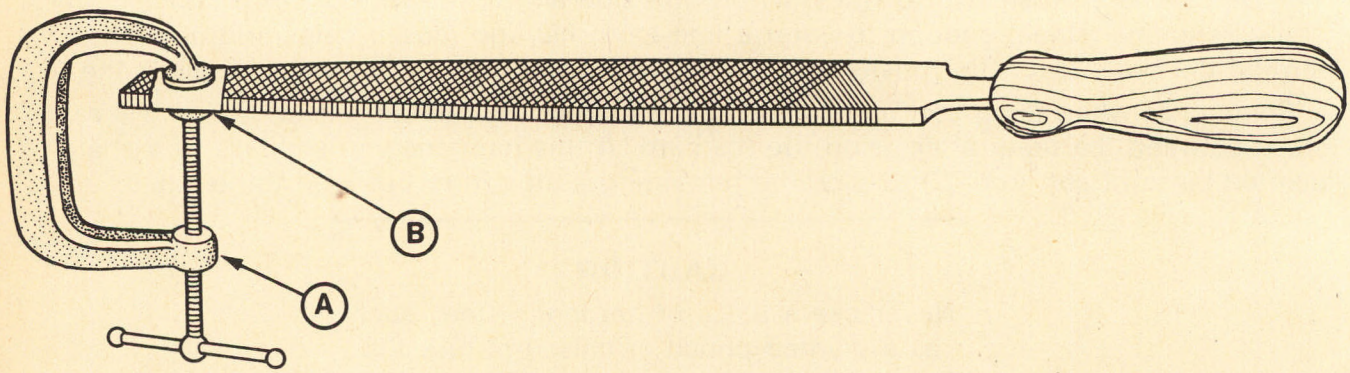


More files wear out by abuse than by use. When not in use, files should be kept separated from each other and from other tools to prevent damage to the file teeth. This may be hard for the mechanic who works out of a tool box, where tools are thrown together constantly.

A simple method of safely carrying your files in a tool box (or any place for that matter) is to fold a piece of cardboard into an accordion shape (A). Each fold should be just wide enough to entirely cover the file blade. Place a file (B) in each fold of the cardboard and fold the "accordion" together. Using a strip of an old inner tube (C) cut approximately ½-inch wide, secure the folds of cardboard (D).

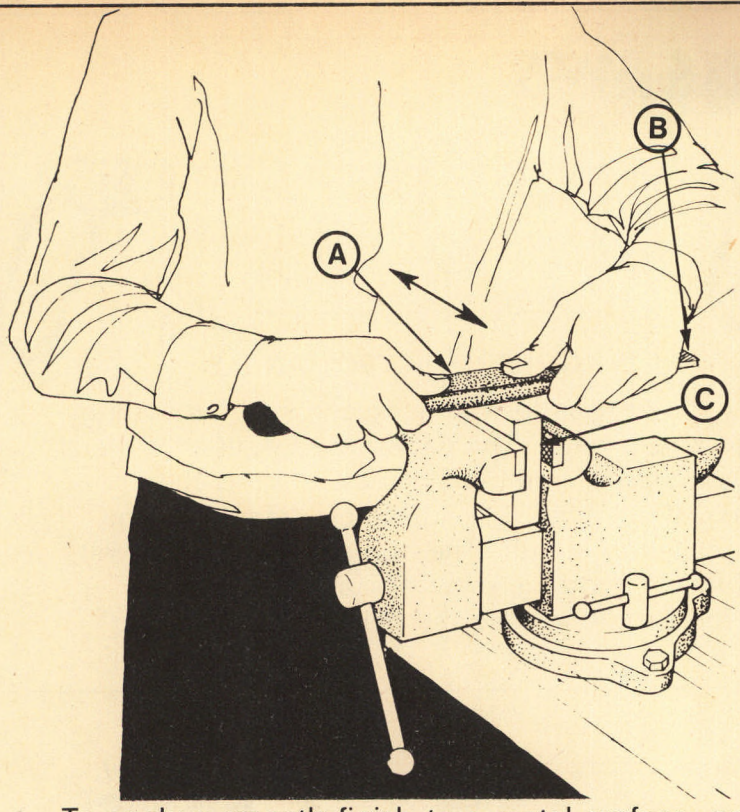
Once your files have been securely wrapped, always store them in a dry place. Rust will adversely affect the cutting edge of file teeth.

HANDY HINTS



There will be times when you must file large amounts of material for prolonged periods of time. Such a job can be made easier if you attach a C-clamp (A) to the file tip (B) and use it as a hand grip for more leverage. Some files have an area at the point where there are no teeth; if so, place the C-clamp in this area. If teeth are present to the very tip of the file face, be sure to add two or three wraps of masking tape to the file tip before attaching the C-clamp.

The length of your filing stroke will be slightly shortened by the C-clamps but you will be much more comfortable doing the job.



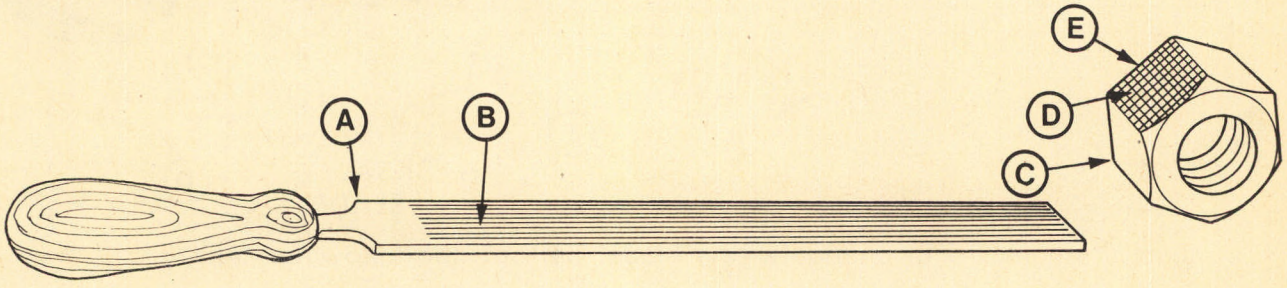
Abrasives are small grains or powders used for smoothing metal surfaces. Some abrasives, such as that in emery cloth and corundum (a form of aluminum oxide), occur naturally and are used in their natural state. The most common abrasives used today are silicon carbide (bluish black) and aluminum oxide (white or brown), which are man-made. Silicon carbide is used to smooth soft metals such as copper, aluminum, etc., while aluminum oxide is used to smooth hard metals. These abrasives can be used in their granular form for smoothing metals, but the best method is to use abrasive cloth, which is coated with these granules. Abrasive cloths or strips are graded by number in the following manner:

- 60 to 80—coarse
- 80 to 100—medium
- 100 to 140—fine

To apply a smooth finish to a metal surface, perform the following steps:

- Obtain a 2-inch strip of the proper grade of abrasive.
- Wrap the strip (A) around the center of a file (B), holding it with your thumbs.
- Apply a small amount of cutting oil to the metal (C) being worked. Move the file back and forth across the metal until the finish you desire is obtained.

Always start with a rougher grade of abrasive, changing to finer and finer abrasive cloth until the material is as smooth as you wish.



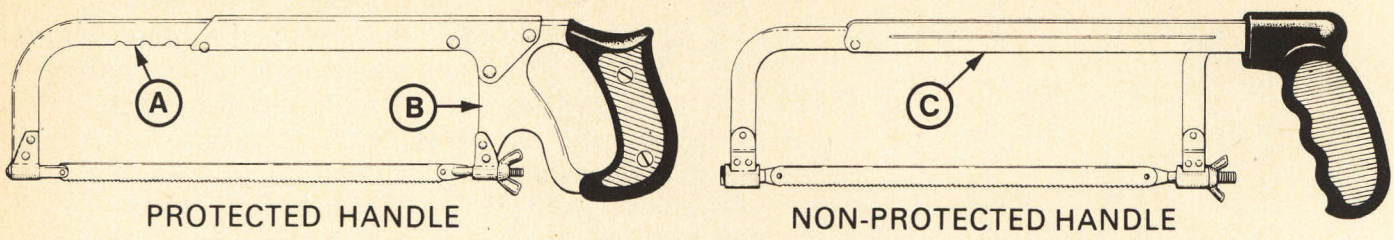
If you've ever wanted to knurl (ridge) a piece of metal for better gripping power but felt it was too costly to send it to a machine shop, there is another method. You can use a checkering file (A). These files are available in cut grades from a No. 000 up to a No. 2, with No. 2 being the coarsest.

The checkering file has straight rows of teeth (B) running the length of the file face. The teeth are extremely sharp for easy cutting of hard materials. Example: If a nut is removed and installed quite frequently and sometimes is hard to remove, the flats (C) of the nut can be knurled by running the file in one direction (D) over the flats, then running the file in the other direction (E), giving the flats a checkered look and your fingers more gripping power.

CAUTION

Do not lift the file from the material being cut after the first forward cutting stroke. Keep the file in the grooves already cut.

HACKSAWS

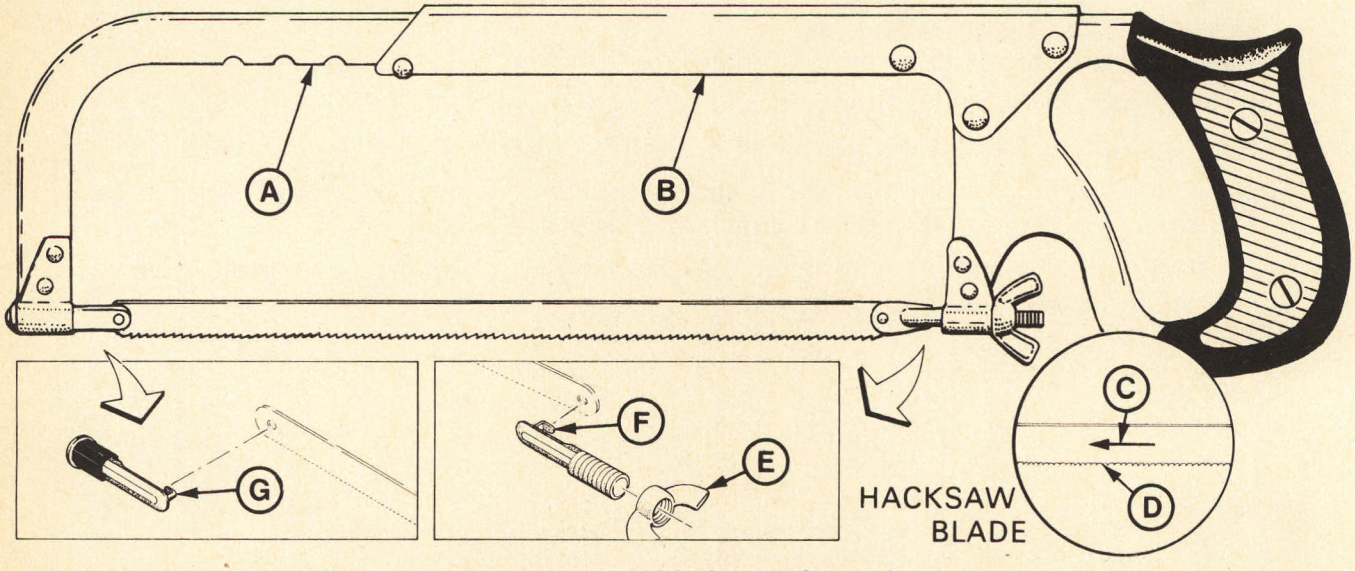


PROTECTED HANDLE

NON-PROTECTED HANDLE

The automotive mechanic will find many varied uses for the hacksaw, such as cutting bolts, screws, metal tubing, rubber hoses and sheet metal. The hacksaw consists of a metal frame, handle and saw blade. To accommodate the different size blades, there is the adjustable type (A) and, of course, the non-adjustable type (C). Adjustable frames can be adjusted to hold blades from 8 inches to 16 inches in length. The non-adjustable type will only hold the one size blade it was intended for. A good hacksaw has a protective handle (B) which encases your hand inside the handle in case the blade breaks or your hand slips off the handle while in motion.

ADJUSTING THE HACKSAW



To adjust the hacksaw or change a saw blade, perform the following steps:

1. Loosen the wing nut (E). Remove saw blade from pins (G,F).
2. Move frame half (B) in or out, depending on the length of the new blade, until desired notch (A) is engaged.

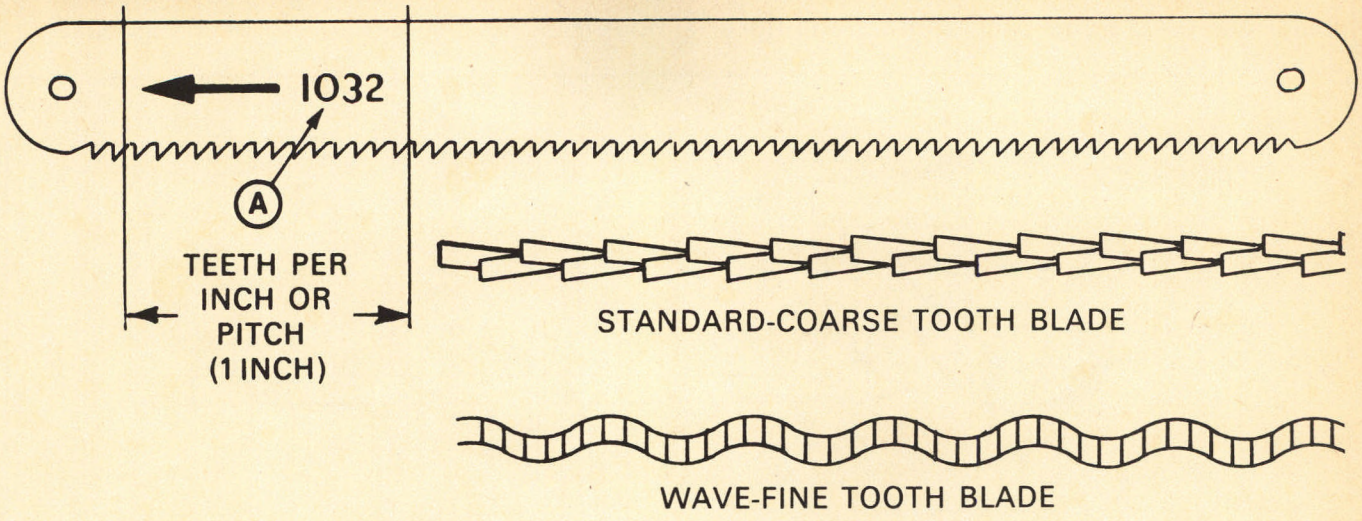
CAUTION

Be sure hacksaw blade is placed on pins (F,G) with arrow (C) on blade pointing forward. If arrow is not visible, teeth (D) of blade must face forward.

3. Place new saw blade on pins (F,G). Pull blade tight toward handle. Tighten wing nut (E) until blade is taut (stiff).
4. Check that blade is straight in frame. If blade is not straight, loosen wing nut, hold blade straight and tighten wing nut.

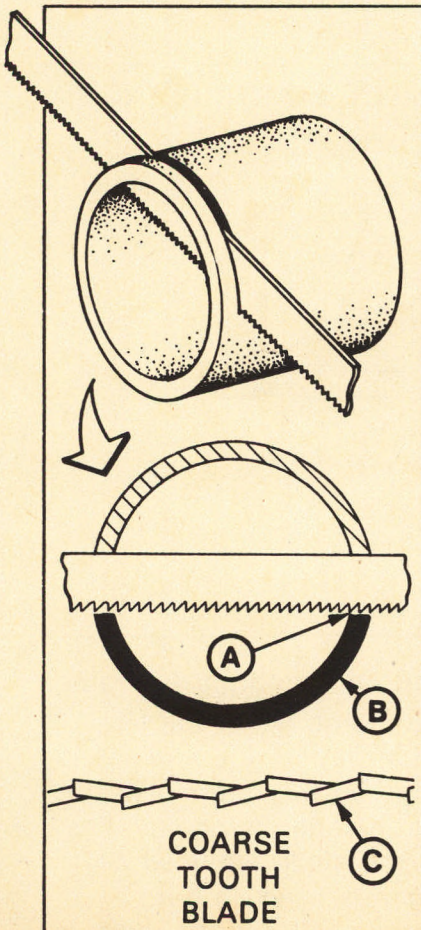
The non-adjustable hacksaw blade is changed exactly the same way. Remember, though, on the non-adjustable hacksaw, be sure you install the same *length* saw blade that was removed.

HACKSAW BLADES



Hacksaw blades are made of hard, tempered (having the right degree of hardness) steel. The blade may be all-hard or flexible. The flexible blade has only the teeth of the blade hardened, while the all-hard blade has been tempered throughout. The pitch (number of teeth per inch) may be 14, 18, 24 or 32 teeth per inch. The part number stamped on each blade is a code number indicating the number of teeth per inch. Example: Code number 1018 = 18 teeth per inch, while code number 1032 = 32 teeth per inch (A), etc.

As mentioned above, hacksaw blades have been tempered, thus making them too hard to be re-sharpened. Once the blade becomes dull, it must be discarded. There is no such thing as an all-purpose hacksaw blade. The right blade must be chosen for the specific job.

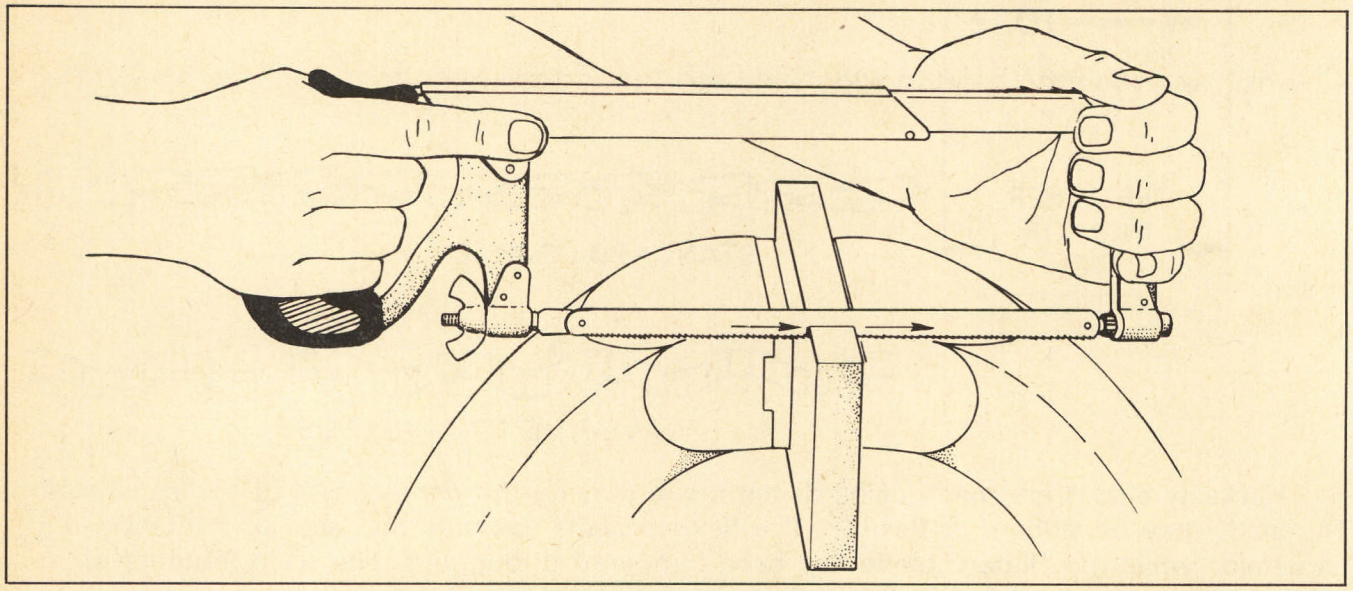


A good rule of thumb to remember in choosing the right blade is to be sure that at least two teeth (A) of the blade are in contact with the material (B) being cut at all times. Soft materials such as aluminum, brass, soft steel and copper should take approximately a 14 teeth-per-inch all-hard blade (all-hard will prevent any wandering of the blade during the cutting stroke), and the harder or thinner materials should take a 32 teeth-per-inch saw blade. (Hard = drill rod, wrought iron, etc. Thin = sheet aluminum, thin wall tubing, etc.) To avoid ruining a hacksaw blade, always test the material to be cut first by taking the edge of a file and running it along the area you are going to cut. If the material cannot be filed, it cannot be cut with a hacksaw.

The teeth (C) are alternately pushed out in opposite directions from the sides of the blade like the teeth of a carpenter's saw. This angle is necessary so that the slot cut by the teeth will be slightly wider than the blade, thus providing the clearance necessary to prevent the blade from sticking. When a saw blade is worn, the points of the teeth wear down and become dull. As the teeth become dull, they straighten slightly and the slot cut by the blade becomes narrower. A dull blade has a tendency to stick in the material being cut, thus breaking easily.

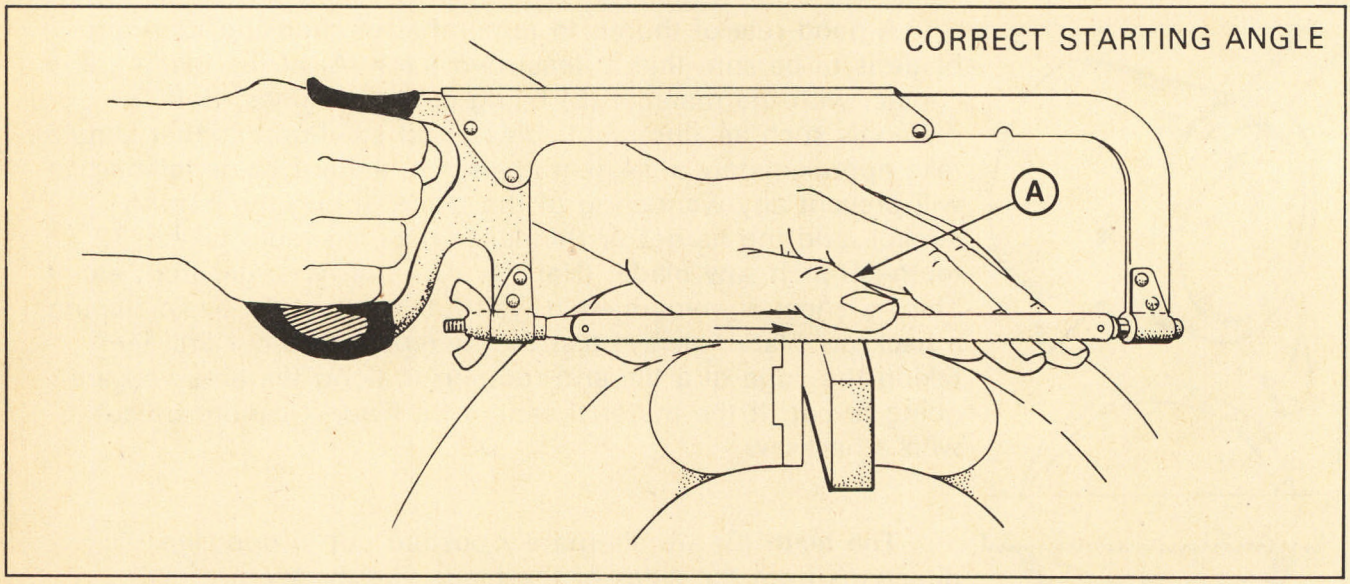
HOW TO USE THE HACKSAW

Most mechanics misuse the hacksaw greatly, making a simple cutting job a difficult operation. With some basic understanding of simple rules, every cutting job becomes easy.



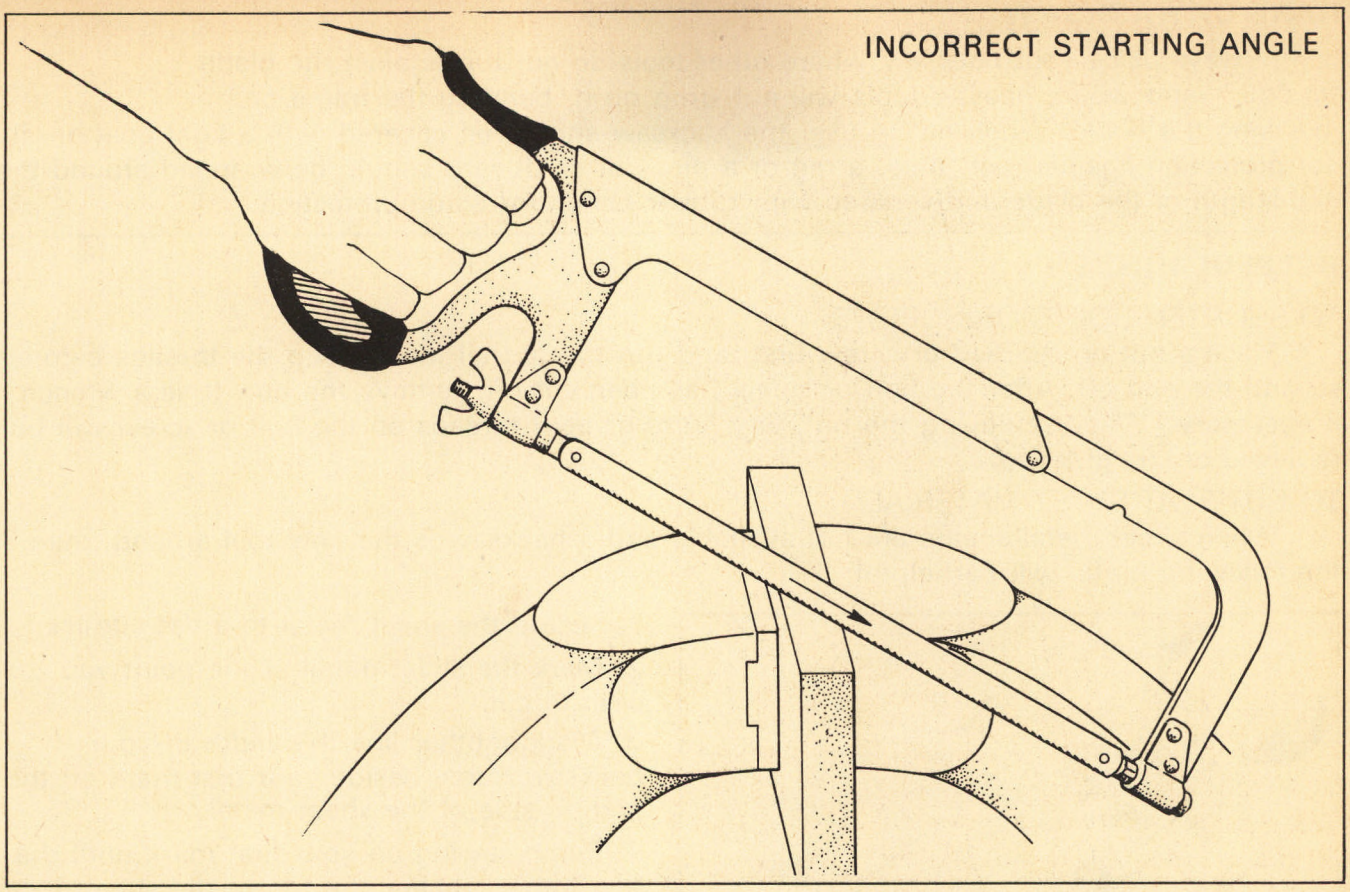
First, be sure the material to be cut is held securely (in a vise or C-clamp). If the material shifts while attempting a cut, the blade may break or the material will be damaged. Second, never start a cut on a piece of material on a sharp edge or sharp angle. This will break or dull the blade teeth and also violate the rule of thumb mentioned earlier about the minimum number of teeth contacting the material to be cut at all times (two).

STARTING THE CUT



Grasp the hacksaw securely, one hand on the grip or handle and one hand on the frame.

In starting the cut, it is a good idea to guide the blade with the thumb (A) of the left hand until the cutting slot is established. Like the file, a hacksaw cuts only on the forward stroke. Use a little downward pressure on the forward stroke but none on the return. Lift the saw *slightly* on the return stroke so that the teeth scarcely touch the material being cut. The stroke should be long and steady so that practically all the teeth on the blade are used. Lighter pressure should be used on soft metals and thin materials than is used on hard metals and heavier materials. Insufficient pressure on the forward stroke will dull the teeth by rubbing them against the metal without cutting it. *Do not rush* when hacksawing. Most



beginners saw too rapidly. Approximately 60 strokes per minute (on the forward stroke) is maximum. A good mechanic uses approximately 40 to 50 strokes per minute with even pressure. He will actually cut through the material faster, his blade will last longer and he will not be as tired as the man sawing too rapidly.

CAUTION

Be sure to keep the saw blade moving in a *straight* line while cutting to avoid any twisting or wobbling of the blade. Use enough pressure on the blade to keep it from becoming pinched or jammed, thus breaking your blade and possibly injuring yourself.

As an aid to cutting, a light oil or cutting fluid can be used. The liquid can be applied to the blade, the material being cut or both.

Broken blades are caused by:
1. Not enough *tension* on blade.
2. Too much tension on blade.
3. Teeth of blade too coarse for material being cut.
4. Too much *pressure* on blade.
5. Frame being twisted while in motion.

Breaking or stripping of teeth is caused by:
1. Too much pressure on blade.
2. Initial cut started at sharp edge or angle.
3. Teeth too coarse for cutting soft stock or thin-walled material.

Dull teeth are caused by:
1. Cutting at too high a speed.
2. Saw frame not being lifted on the *back* stroke.
3. Improper selection of blade.
4. Teeth pointing to rear instead of forward.
5. Pressure too light on cutting stroke.

Crooked cut is caused by:
1. The blade being dull.
2. The blade requiring tightening.
3. The frame being out of alignment.
4. Just plain sawing at a crooked angle.

HACKSAWS

CARE OF HACKSAW

Always place your hacksaw where other tools do not rub against the blade to dull it and where heavier tools will not drop on it, bending the frame or breaking the blade. When not in use, the hacksaw should be covered with a light coat of oil for protection against rust. Also, a rag or a piece of cardboard should be wrapped around the full length of the blade and secured with rubber bands for blade protection.

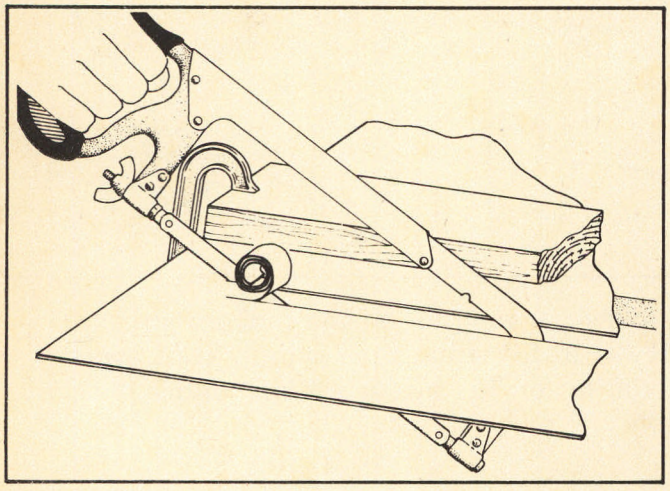
HELPFUL HINTS

TO SHORTEN BOLTS OR SCREWS:

Place a nut on the bolt or screw first, and run the nut all the way up the threads before sawing the end off. After the bolt or screw has been cut off, remove the nut. (Use a wrench if necessary.) When removing the nut, any burrs or bent threads on the bolt or screw will be removed or straightened.

TO CUT FLAT SHEET MATERIAL:

When sheet metal shears are not available and a hacksaw is the only tool around, then the following hints will be helpful:

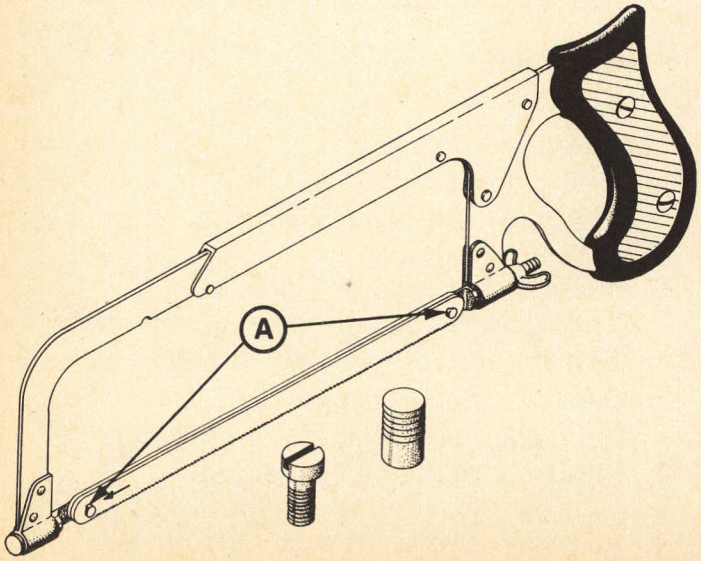


1. Secure the sheet metal to a flat surface.
2. Mark the sheet metal at the point you wish to cut.
3. Mark another line the width of your hacksaw frame beside your first mark on the "scrap" side of the sheet metal.
4. Begin sawing on your first mark until the saw frame touches the top of the sheet metal.
5. Remove the saw and begin cutting on the second line until the saw frame just touches the top of the sheet metal.
6. Remove the saw and roll the center section of the cut sheet metal toward you.

Continue these steps, alternating back and forth between the marked lines until the sheet metal has been cut in half.

TO CUT SCREW OR STUD SLOTS:

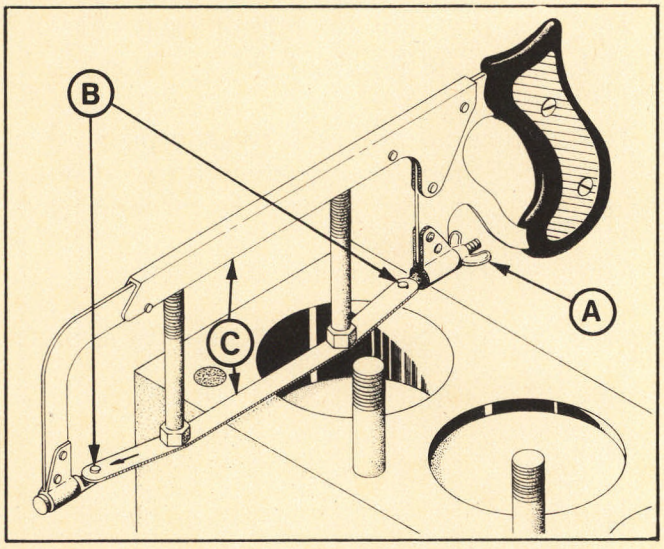
There are thick saw blades on the market for cutting larger screw slots or slots in studs. The blade thicknesses come in .049, .065, .083 and .109-inches, but if you do not have one of these blades, the following hint will be helpful:



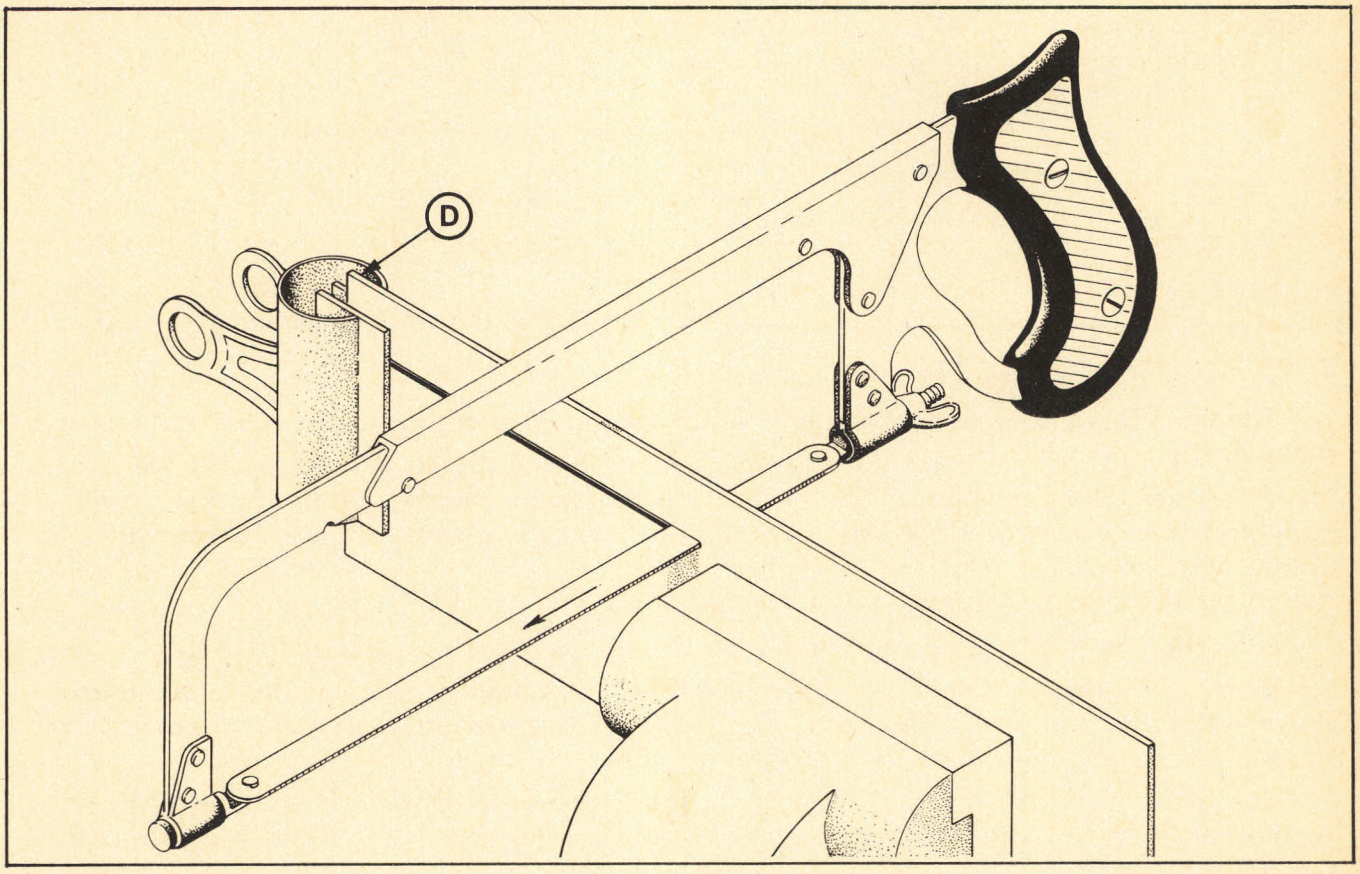
To enlarge the screwdriver slot in a screw or cut a slot in a stud, simply add one saw blade on the pins (A) next to the existing blade. (Be sure the new blade has the same number of teeth-per-inch as the blade already in the hacksaw.) Place blades in existing slot and begin sawing. Excess material will be cut away, enlarging slot.

TO CUT OFF STUDS OR BOLTS FLUSH:

To save time and to prevent setting up and using machine tools, you may want to cut off existing studs flush to a surface. It can be done using the hacksaw. Be sure to use a flexible blade for this operation:



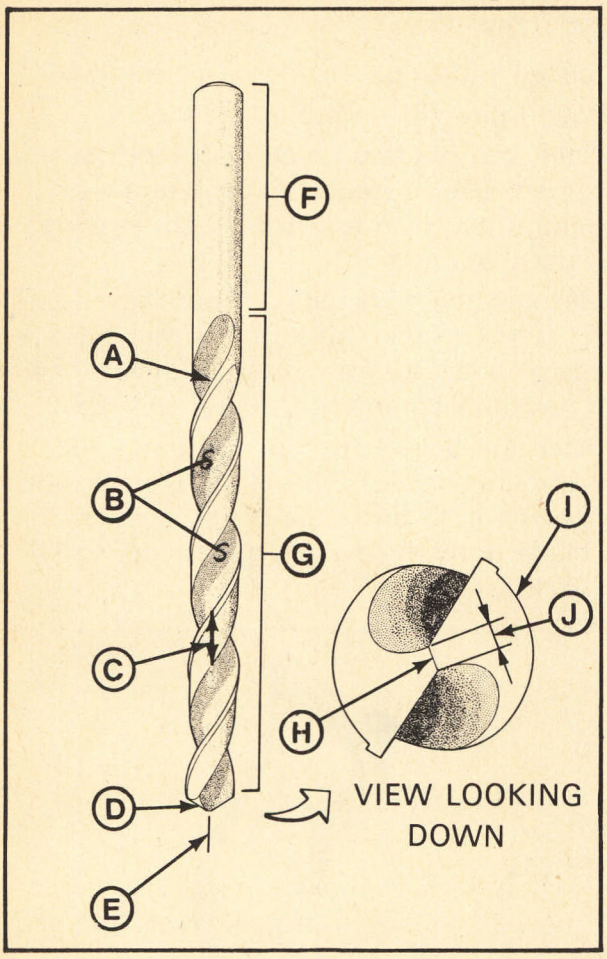
1. Loosen wing nut (A). Remove saw blade.
2. Rotate pins (B) until pins face up.
3. Place saw blade on pins with teeth facing to the left. (Don't forget that the angle of the teeth must face forward.) Tighten wing nut until blade is tight.
4. Measure the distance (C) from the bottom of the frame to the side of the saw blade. A couple of bolts approximately ¼-inch longer than your measurement usually work best.
5. Place the bolts between the frame and saw blade as shown. The blade is now bent at two points to bring the center section of the blade down below the obstructions of the hacksaw frame.



The same procedure used in cutting off studs flush to a surface applies here in cutting thin sheet material, except that nothing is used to lower the center section of the saw blade:

1. Place thin sheet material in a vise after marking area to be cut.
2. Again, place the saw blade with the teeth facing to the left.
3. As you begin to saw the thin material, it will become very wobbly and tend to throw you off your cutting course.
4. Place a woman's bobby pin or spring clip (D) at the end of the thin material being cut. This will prevent it from jumping around.

DRILLS AND MOTORS



PARTS OF A TWIST DRILL

The twist drill is the most common type of drill and is used for drilling metals, plastics, wood, etc.

The purpose of this odd, twisted piece of hardened Tool Steel is to produce a round hole in materials sometimes as hard as the drill itself.

A drill consists of the following parts:

1. Margin (A), the cutting edge around the body.
2. Flutes (B).
3. Shank (F).
4. Body (G).
5. Heel (I).
6. Dead center (H).
7. Axis (E), the centerline of the drill.
8. Lip (D), the cutting edge.
9. Body clearance (C).
10. Web (J), width of dead center.

A drill and its parts function as follows:

The lips (D) are the parts of the drill which perform the cutting.

The flutes (B) help to form the proper cutting angle to the lip (D) and permit the drill to cut more freely with less power. They cause the chip to curl tightly within itself so it will come away freely. Last but not least, the flute (B) allows lubricant to flow easily down to the cutting edge.

The second angle that forms the cutting edge on lip (D) is the heel (I). For the most part, this is the only surface that is reground when a drill becomes dull and will not cut.

Body clearance (C) is smaller in diameter than the margin (A). This is to reduce friction between the drill and the walls of the hole. However, the margin (A) is the full diameter of the drill and extends the full length of the flute (B).

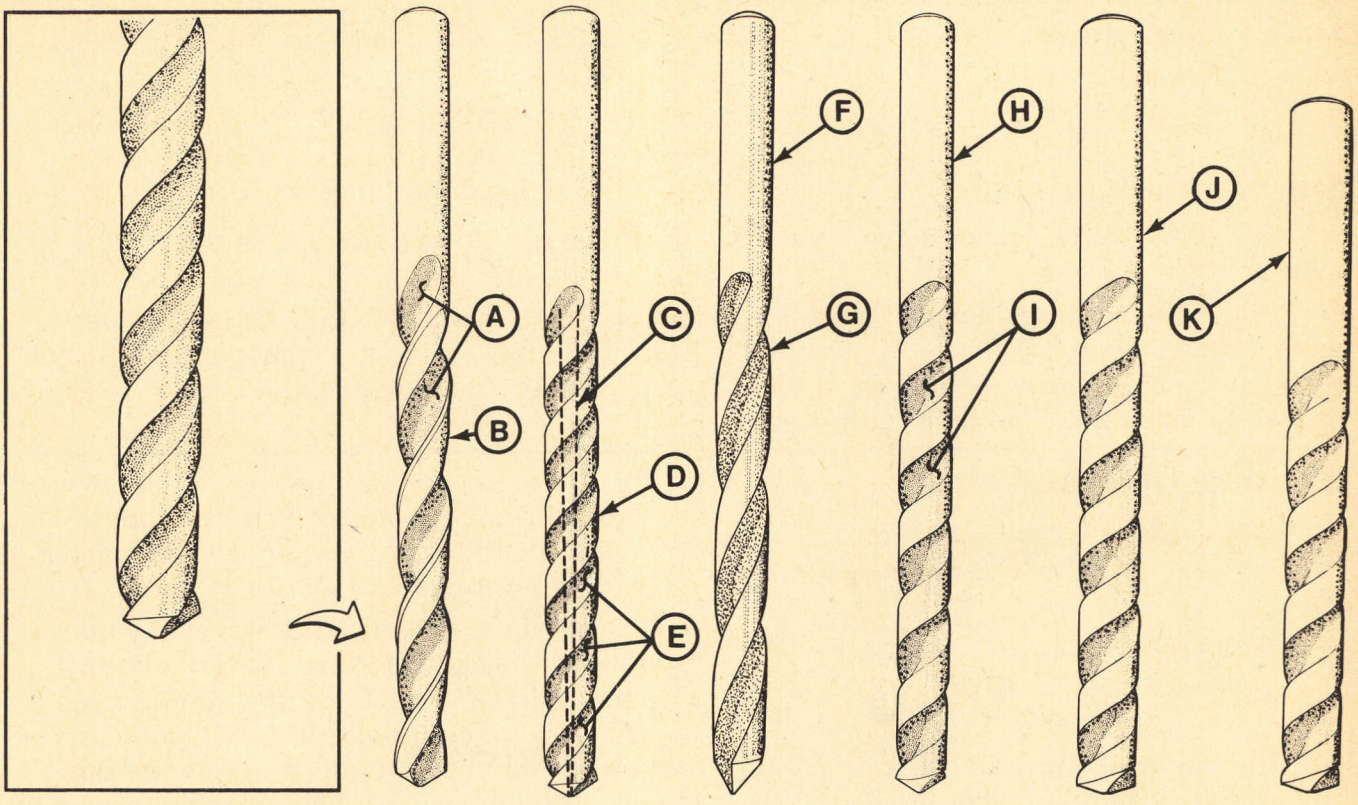
The dead center (H) is the sharp edge at the extreme tip of the drill. It is formed by the intersection of the two cone-shaped surfaces of the point and should always run true to the axis (E) of the drill.

Damage to the shank (F), the part of the drill that is held in a drill chuck, is the most common cause of drill failure. If such damage occurs, the drill will not run concentric (true) about its axis (E).

CAUTION

Be sure that the shank (F) is free of burrs (rough edges) that might cause the drill to run out (wobble).

TYPES OF COMMON DRILLS



Inexpensive drills are made of Carbon Steel. The more expensive drills, especially those designed to cut the tougher metals, are made of high-speed alloy (two or more metals) steel. The latter last longer and therefore are most widely used.

The twist of the flutes (A) and the thickness of the web (C) determine the type of work for which the drill is best suited.

Drill (B) is an all-purpose drill. It can be used on most materials, such as cast iron, steel, steel forgings, sheet metals, plastics, aluminum and wood.

Drill (D) shown above has ''fast'' spiral flutes (E). That is, there are more twists per inch than are used on a general-purpose drill (B). This drill is used on aluminum, die-cast metal, copper, slate, etc.

On such metals as mentioned earlier, it helps if the drill flutes are polished, along with the fast spiral flutes. The drill can then eject chips quickly and easily.

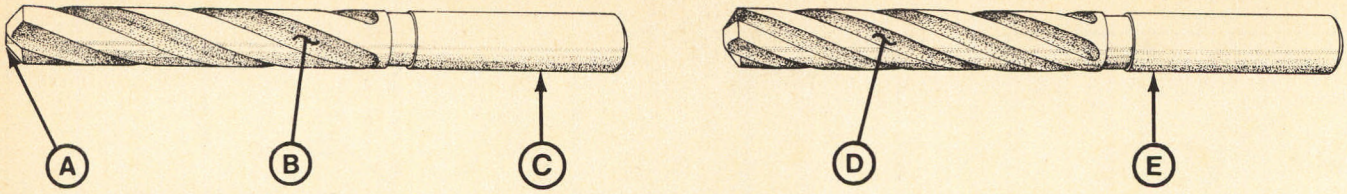
Drill (F), however, has a longer twist to its flutes (G). This type of drill is used on such materials as Bakelite, hard brass, fiber, hard rubber and various molded plastics.

Drill (H) is suitable for heavy-duty drilling in tough metals. The flutes (I) on this type of drill have more twists per inch than that of the general-purpose drill (B) and not quite as many twists as that of drill (D). They also have a heavier web that enables them to withstand the increased strains produced in drilling heat-treated alloy steel forgings.

Drill (J) is especially useful in the automotive industry on sheet metals, using air or hand drills. This drill is of heavier construction than a general-purpose drill and has a smooth finish that prevents the material from binding or building up on the drill when in use.

The toughest of all drills (K) is designed for drilling types of stainless steel and iron that are difficult to machine. It has a shorter overall length than the common drill (B) and a thicker web (C), enabling this drill to withstand the pressures involved in drilling tough metals.

SPECIAL DRILLS

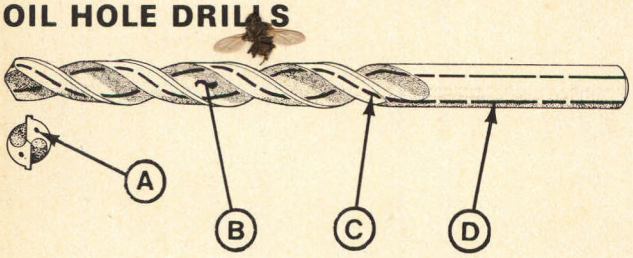


MULTI-GROOVE DRILL

The drills in this section have special features designed to perform special tasks in a more efficient manner.

Drill (C) has three flutes (B), a shallow angle and a flat point (A). Drill (E) has all the same features as drill (C) except that drill (E) has four flutes (D). Both of these drills are used to follow a hole already made by a smaller drill (pilot hole), thereby enlarging cored holes (these are holes that already exist in castings).

OIL HOLE DRILLS

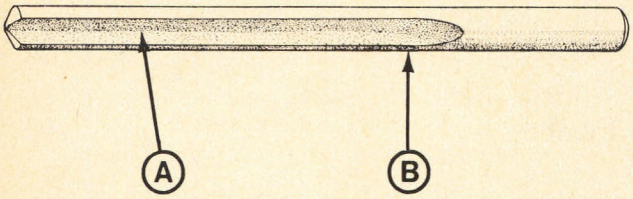


The average automotive mechanic will probably not use an oil hole drill, but if you ever run across one you should be familiar with what it is and how to use it.

Oil hole drills (D) are provided with internal holes (C) through which lubricant can be forced directly to the cutting edge (A) while drilling holes in hard materials.

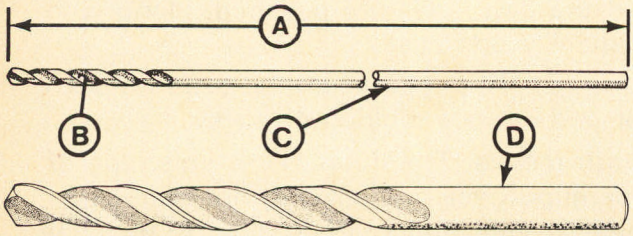
The lubricant, besides reducing friction, acts as a cooling agent and prevents the drill point (A) from burning when drilling at high speeds. The lubricant and chips escape through the flutes (B) of the drill in the same manner as when using ordinary drills. These drills are used primarily for machine work to produce long, deep holes in metal.

STRAIGHT-FLUTE DRILLS



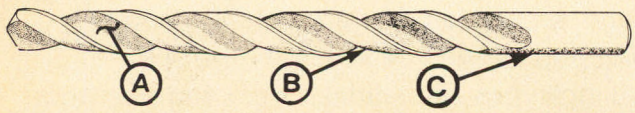
Drill (B) has straight flutes (A) which are designed to work in soft materials like brass and soft cast alloys. They are also suitable for use on thin sheet materials. This drill will not ''grab'' the material as it breaks through the surface, thus producing a true hole with little risk of breaking the drill.

EXTENSION DRILLS



Extension drills (C) are available in different lengths (A); 12 inches is the most common. The flutes (B) of a 12-inch extension drill will occupy only about 2 inches of the drill's total length. The remaining stock is devoted to the shank (C). Extension drills are used for drilling holes in places which cannot be reached by the standard drill (D) of ordinary length.

SKIN DRILLS



A skin drill (B) has flutes (A) extending over most of its length and has a very short shank (C). This drill is much shorter than the common drill. The advantage of the skin drill is that it can be sharpened a great many times; thousands of holes can be drilled before discarding it. The purpose and design of the skin drill is for drilling a great many holes in quick succession in aircraft skin, auto bodies and situations where sheet stock is used extensively.

DETERMINING DRILL SIZE

DECIMAL EQUIVALENTS
SHOWING NUMBER, LETTER AND FRACTIONAL SIZE DRILLS

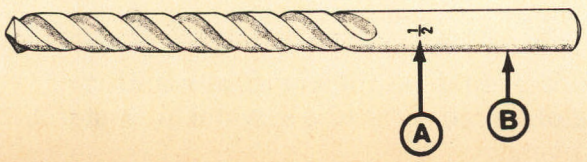
DRILL SIZE	DECIMAL INCHES	DRILL SIZE	DECIMAL INCHES	DRILL SIZE	DECIMAL INCHES	DRILL SIZE	DECIMAL INCHES	DRILL SIZE	DECIMAL INCHES	DRILL SIZE	DECIMAL INCHES
80	.0135	54	.0550	1/8	.1250	7	.2010	O	.3160	37/64	.5781
79	.0145	53	.0595	30	.1285	13/64	.2031	P	.3220	19/32	.5937
1/84	.0158	1/16	.0625	29	.1360	6	.2040	21/64	.3281	39/64	.8094
78	.0160	52	.0635	28	.1405	5	.2055	Q	.3320	5/8	.6250
77	.0180	51	.0670	9/64	.1406	4	.2090	R	.3390	41/64	6408
78	.0200	50	.0700	27	.1440	3	.2130	11/32	.3437	21/32	.6562
75	.0210	49	.0730	28	.1470	7/32	.2187	S	.3480	43/64	.6719
74	.0225	48	.0760	25	.1495	2	.2210	T	.3580	11/16	.6875
73	.0240	5/64	.0781	24	.1520	1	.2280	23/64	.3594	45/64	.7031
72	.0250	47	.0785	23	.1540	A	.2340	U	.3680	23/32	.7187
71	.0280	46	.0840	5/32	.1562	15/64	.2344	3/8	.3750	47/64	.7344
70	.0290	45	.0820	22	.1570	B	.2380	V	.3770	3/4	.7300
69	.0292	44	.0860	21	.1590	C	.2420	W	.3860	49/64	.7658
68	.0310	43	.0890	20	.1610	D	.2460	25/64	.3906	25/32	.7812
1/32	.0313	42	.0935	19	.1660	1/4	.2500	X	.3970	51/64	.7969
67	.0320	3/32	.0937	18	.1695	F	.2570	Y	.4040	13/16	.8125
66	.0330	41	.0960	11/64	.1719	G	.2610	13/32	.4082	53/64	.8281
65	.0350	40	.0980	17	.1730	17/64	.2656	Z	.4130	27/32	.8437
64	.0360	39	.0995	18	.1770	H	.2680	27/64	.4219	55/64	.8594
63	.0370	38	.1015	15	.1800	I	.2720	7/18	.4375	7/8	.8750
62	.0380	37	.1040	14	.1820	J	.2770	29/64	.4531	57/64	.8906
61	.0390	36	.1085	13	.1850	K	.2811	15/32	.4687	29/32	.9062
60	.0400	7/64	.1093	3/16	.1875	9/32	.2812	31/64	.4843	39/64	.9219
59	.0410	35	.1100	12	.1890	L	.2900	1/2	.5000	15/16	.9375
58	.0420	34	.1110	11	.1910	M	.2950	33/64	.5156	61/64	.9531
57	.0430	33	.1130	10	.1935	19/64	.2968	17/32	.5312	31/32	.9657
56	.0465	32	.1180	9	.1960	N	.3020	35/64	.5469	63/64	.9844
3/64	.0469	31	.1200	8	.1990	5/16	.3125	9/16	.5625	1	1.000
55	.0520										

The decimal equivalent table (A) shows how drill sizes are expressed. They are expressed in number, letter and fractional size of drills. Starting at the upper left corner of this table at column (B), reading down in each of the columns and moving to the right, you will find the drills numbered from 80 to 1 inclusively. The number 80 drill is the smallest size given, having a diameter of .0135-inch as indicated in column (C). The number 1 drill is the largest of the number series and has a diameter of .2280-inch.

At intervals in the numbered series, you will find certain drill sizes expressed in fractions of an inch, such as 1/64-inch, 1/32-inch, 3/64-inch, etc. Notice that the fractional drills increase in size by steps of 1/64-inch; in other words, a 1/32-inch drill is 1/64 inch larger than a 1/64-inch drill, a 3/64-inch drill is 1/64-inch larger than a 1/32-inch drill and so on throughout the table.

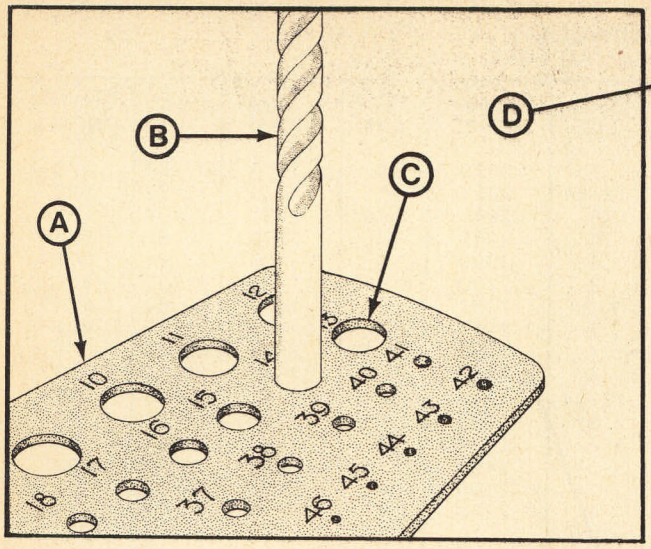
Directly under drill No. 1 in column (D), you will find the letter "A" used to designate another series of drills; the actual diameter of drill "A" is given in column (E), shown here as .2340. It is lettered instead of numbered, ranging from size "A" at .2340-inch to size "Z" at .4130-inch (F).

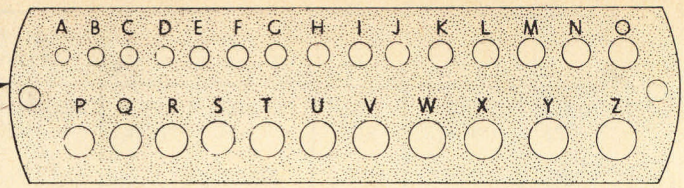
Throughout the balance of this table, the drill sizes are arranged according to their actual diameters and are expressed in fractions of an inch. That is, starting with a 27/64-inch drill directly under "Z" (F), each succeeding drill size is 1/64-inch larger in diameter than the one preceding it. The table ends with a drill of 1.00-inch diameter. However, the diameters of all drills larger than 1 inch are also expressed in inches and fractions of an inch and increase in steps of 1/64-inch. Example: The next size over 1 inch would be 1-1/64-inches, then 1-1/32-inches and 1-3/64-inches.



The decimal table above not only gives the drill sizes but also supplies the exact diameter of each drill, expressed in decimals of an inch. The size (A) of most drills listed in the table is stamped on the shank (B), either as a letter or as a fraction of an inch.

DRILL SIZE GAUGES



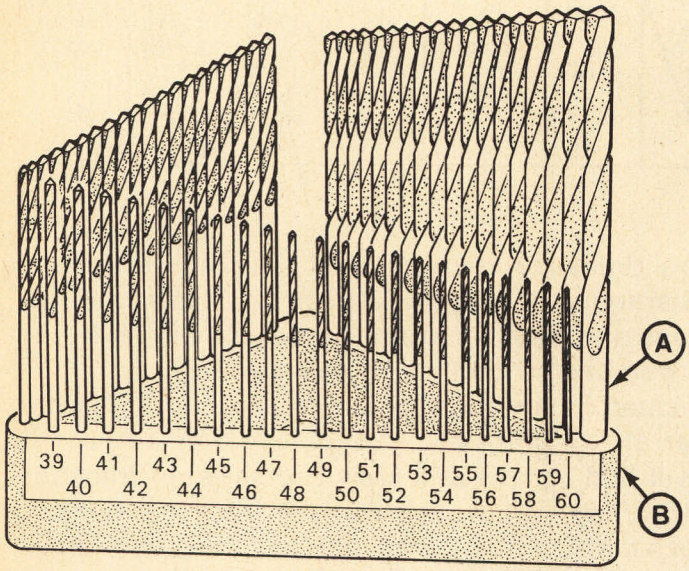


Drill size gauge (A) is made to fit all the drills that exist in a NUMBER set (from 80 to 1).

Drill size gauge (D) is designed to fit all LETTER-size drills. There is also a gauge made to fit FRACTIONAL drills.

No. 80 is the smallest size drill that exists in the three drill sets mentioned. This drill has a diameter of .0135-inch. As you can see, it is not possible to stamp the number 80 on this drill, hence the drill gauge.

The drill gauge (A) is one way of differentiating one size of drill from another. In order to do this, pass the drill (B) into a hole (C) of the gauge until the drill fits snugly. At this point, the size given on the drill gauge is the size of the drill being tested.

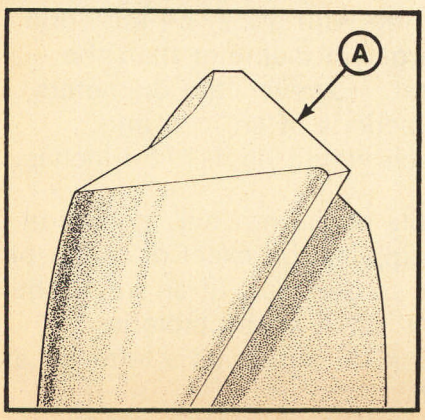


DRILL SETS

So that no time will be lost in selecting a drill of the size required for a certain job, drill set (B) is used. The drill set shown holds drills from 1 to 60. The shank (A) of each drill fits snugly in its proper hole. Each hole is marked with its size.

HOW TO SHARPEN DRILLS

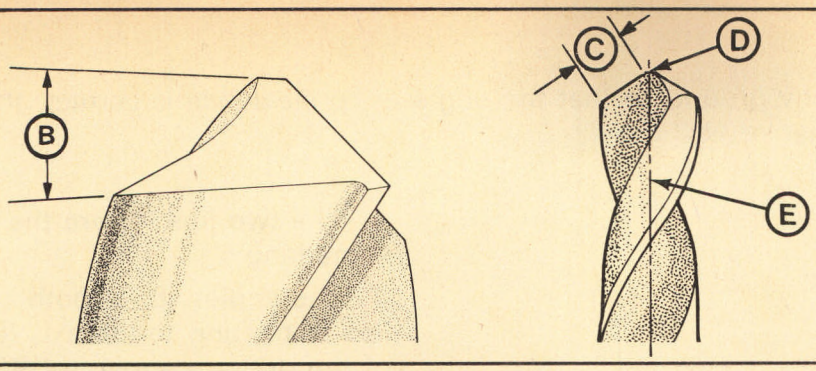
The importance of correctly grinding twist drills cannot be too strongly emphasized. A drill, no matter how well designed or heat-treated, will fail in its performance if the point is not ground properly. The greatest percentage of failures experienced in drilling are caused by incorrect repointing.



For best results, a drill should be reground or repointed at the first sign of dullness along the cutting lip (A). Failure to do so may cause the drill to break due to the increased load imposed on the cutting edges by the dullness.

CAUTION

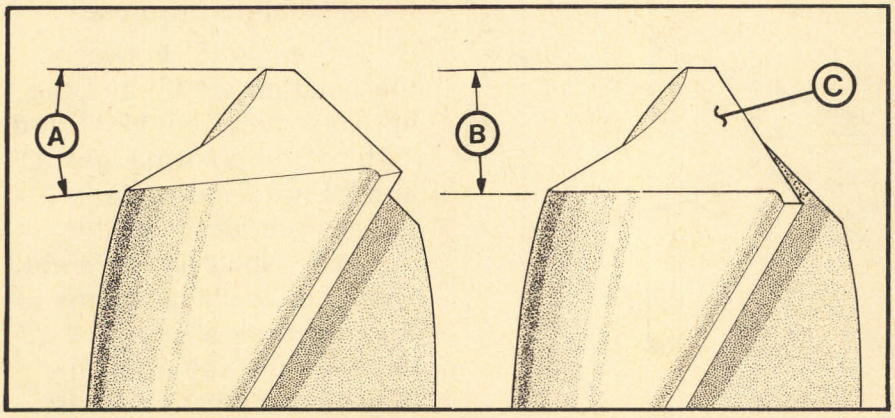
If a drill is allowed to become too dull before repointing, it will be necessary to grind off a considerable amount of material before a new and correct point can be obtained, which is obviously wasteful.



When grinding a drill, the following three factors must be considered:

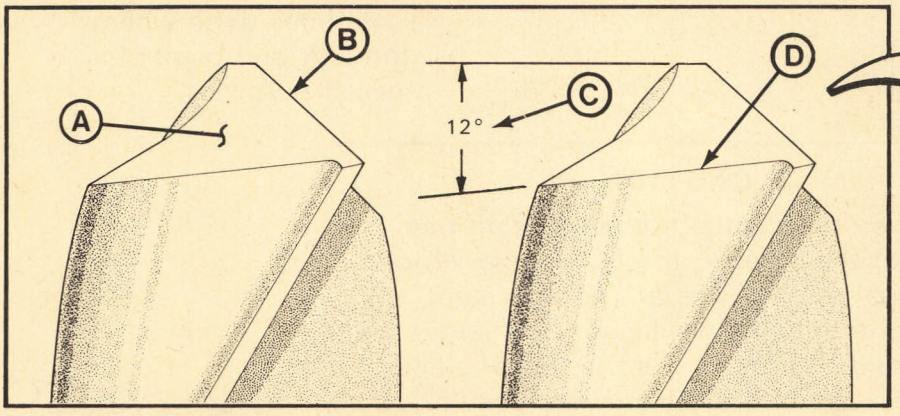
1. Lip clearance angle (B).
2. Length of the lips (C).
3. Location of the point or dead center (D) in relation to the axis (E).

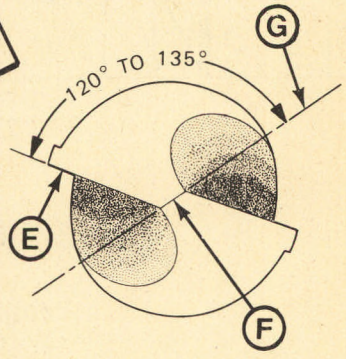
GRINDING LIP CLEARANCE



Lip clearance (A) is the most misunderstood angle of a drill. It is the angle and face that must be reground when a drill becomes dull.

A drill that has no lip clearance (B) could not cut into a piece of steel, because the surface (C) would always be in contact with the metal. Such a drill would merely rub on the steel surface without penetrating it.





Therefore, if the lip (B) is to penetrate (if its edge is to cut), we must grind away the surface (A) back of the lips (B). Grinding away surface (A) gives a drill ''relief'' so that the lip can penetrate the metal.

Surface (A) is referred to as the heel and should be ground away at an angle of 12° (C). In all cases, this angle of 12° is the angle at the circumference (D), that is, the outer edge of the drill.

Looking down on the drill point, if the correct clearance of 12° is given to the lip (E), an angle will have been produced between the point on dead center (F) and the lip (E). This angle should be between 120° and 135° (G).

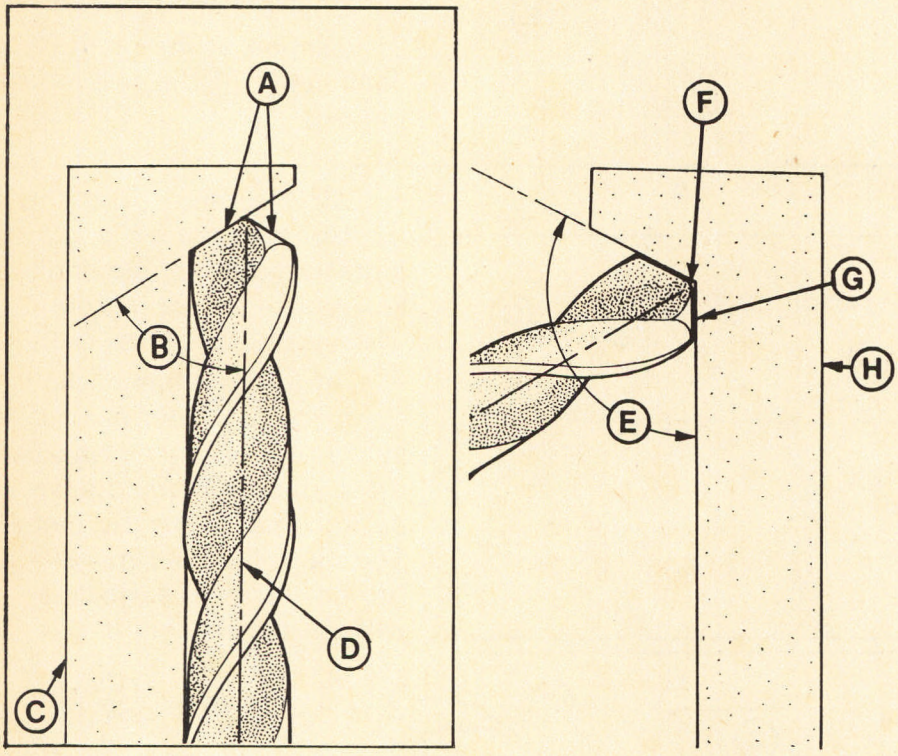
CAUTION

If the angle of the lip clearance is too great, the edges of the cutting lips will break down because they will not have sufficient material backing them to support the lip.

If not enough lip surface is ground away, the clearance of the point will be so reduced that it will cease to be a cutting edge and refuse to bite into the metal. This condition can result in splitting the drill up the center.

USING DRILL POINT GAUGES

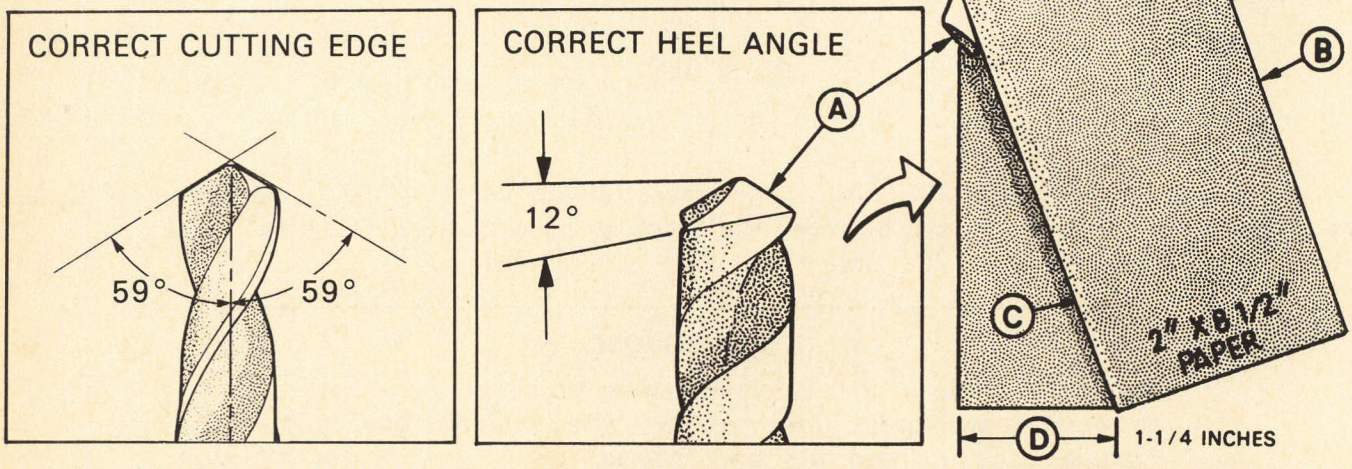
After the point has been properly ground so that the angle of lip clearance is correct, the point must be checked to ensure that:



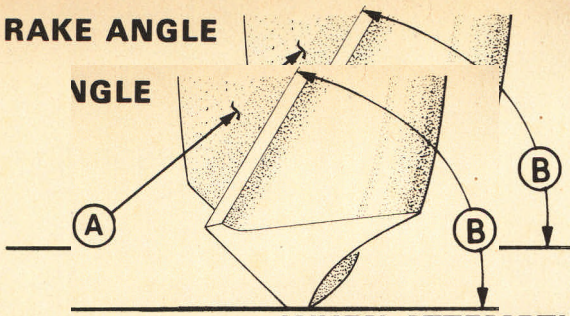
1. The two lips (A) are the same length.
2. The angles (B) of both lips in relation to the axis (D) of the drill are equal at 59°. This angle is recommended for general-purpose use.
3. The angle (E) between the dead center (F) and the lip (G) is between 120° and 135°. Drill point gauges (C and H) are fixed-angle gauges produced for this purpose. However, different types are available. Some of them provide a means whereby the setting of the angle can be varied, as is sometimes done when grinding drill points for special purposes.

CAUTION

If the drill point is not equal from one side to the other (if the 59° angle is not equal and the lips are not the same length), the drill will produce a hole larger than the drill. Excessive wear to the drill and damage to the material will result.



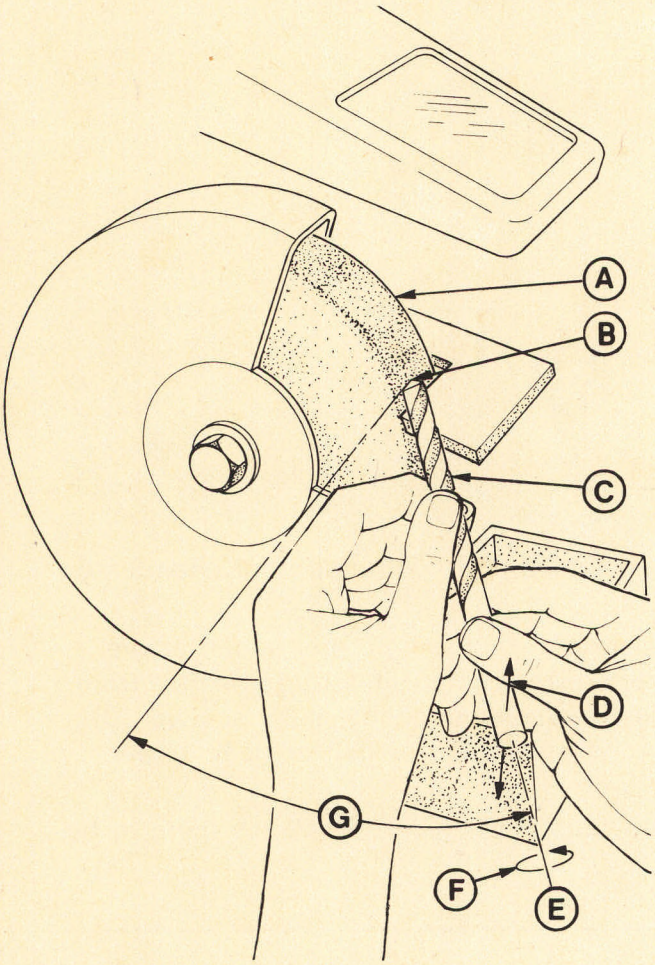
A quick way to check the correct heel angle (A) of a drill is to use a piece of paper (B) 8-1/2 inches long and 2 inches wide. Place a mark 1-1/4 inches (D) along one edge of the paper. Wrap the paper around the drill, keeping one edge of the paper along the heel angle. The edge (C) of the paper should line up with the mark on the paper if the heel angle is correct.



Rake angle (B) is designed into a drill. As stated earlier, it is produced by the twist of the flutes (A). However, this angle and others will change in some series in order to function better in cutting some materials. Be sure to select the right drill for the cutting job.

WARNING

WHEN ATTEMPTING TO GRIND ANYTHING ON A BENCH GRINDER, SAFETY GLASSES MUST BE WORN.



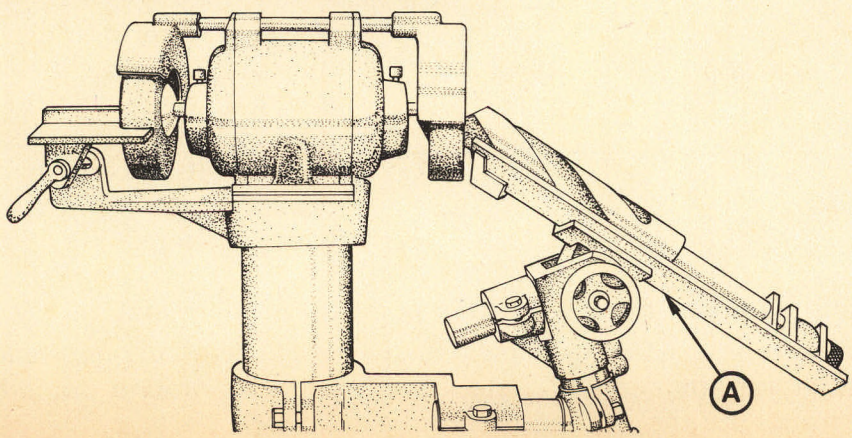
To produce a drill point correctly by hand requires a lot of practice. Practice is required because two or more movements take place at the same time.

To sharpen a drill on a conventional grinder (emery wheel [A]), hold the drill (C) against the face of the wheel so that the centerline (E) of the drill will be at a 59° angle (G) with the face of the wheel. This will produce the correct angle on the drill lip (B).

Press the point of the drill (C) against the wheel lightly. Be careful not to hold the drill against the emery wheel too long or the metal will burn. Frequently dip the drill end into water to preserve the temper (hardness) of the drill. During this procedure, use your left hand as the fulcrum and place your right hand near the end of the shank so that you can control the angular (up and down [D]) position of the drill.

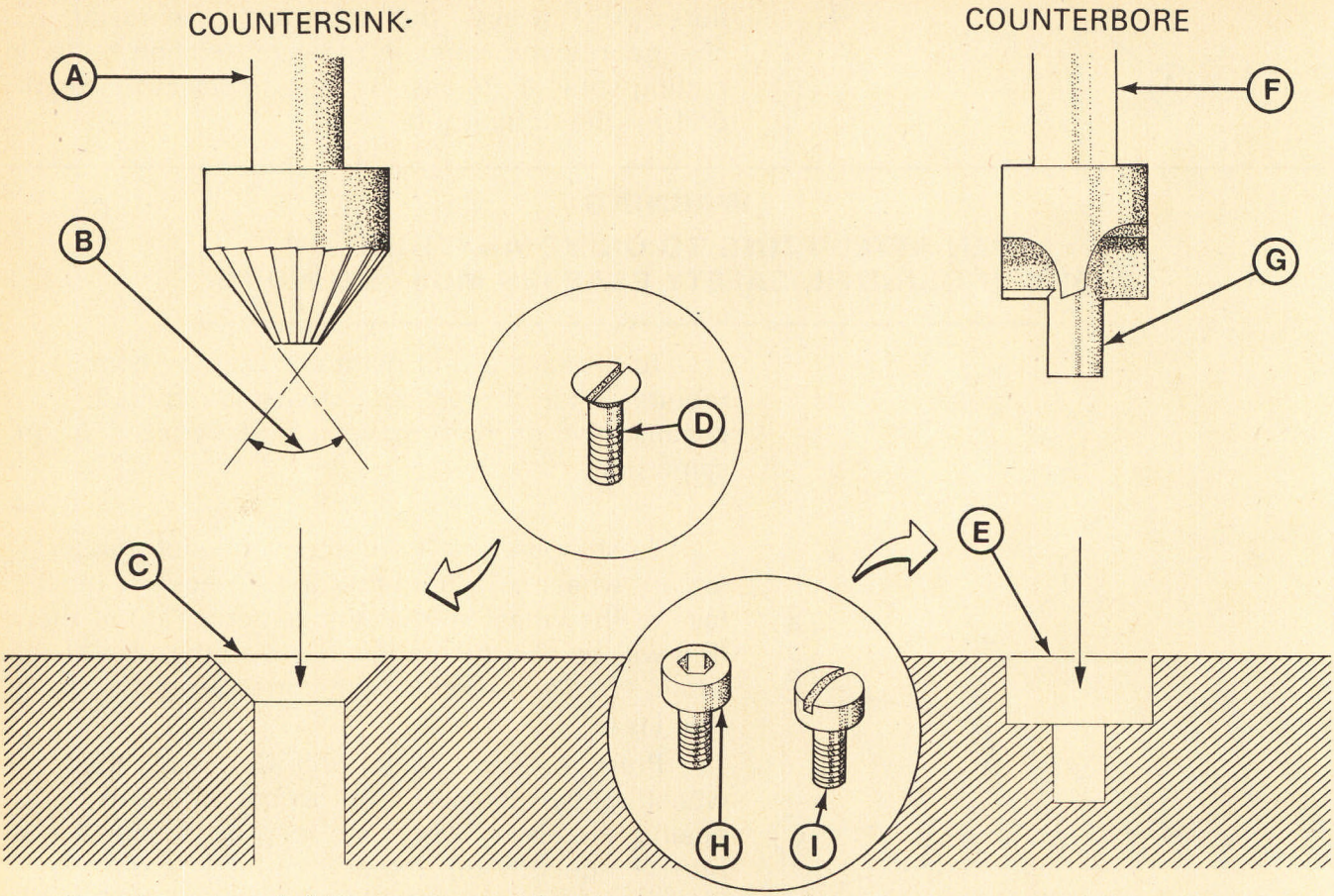
While contacting the face of the wheel, move the drill slowly downward in the direction of the arrow (D) to an angle of about 30°. At the same time rotate the drill in the direction of arrow (F). Repeat this movement for both sides of the drill until all the conditions and angles described earlier are produced.

DRILL GRINDING ATTACHMENT



In shops where a great deal of drill grinding is required and a high degree of accuracy is a must, it is generally the practice to use a precision drill grinding attachment (A). There are many different types available today. For the proper procedure in the use of the attachment, refer to the manual supplied with the attachment.

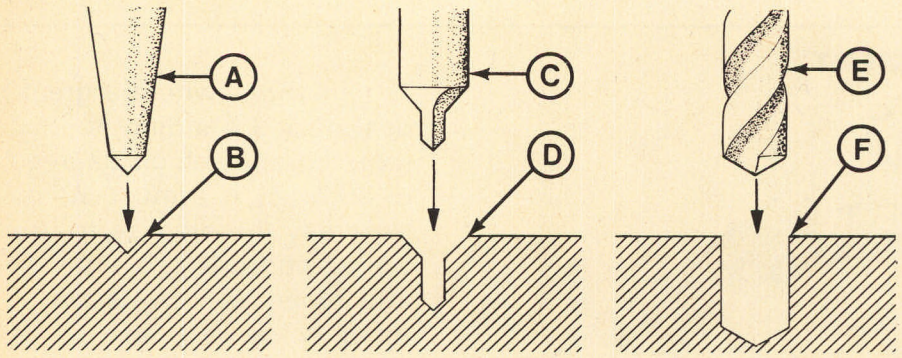
COUNTERSINKS AND COMBINATION DRILLS



Certain types of drilling jobs require that a hole be drilled and countersunk or chamfered (C) or drilled and counterbored (E).

These drills are just a few that are used to produce holes of the type mentioned above. First there is the countersunk drill (A). These drills are available with different angles (B) from 60° to 80° and are used when you wish to install flathead screws (countersunk screws) (D). Next is the counterbore drill (F), used when installing cap screws (H) or fillister head screws (I) that must be recessed and flush with a surface.

The better quality counterbore drills (F) have removable pilots (G). This allows them to be used in different sized drill holes.

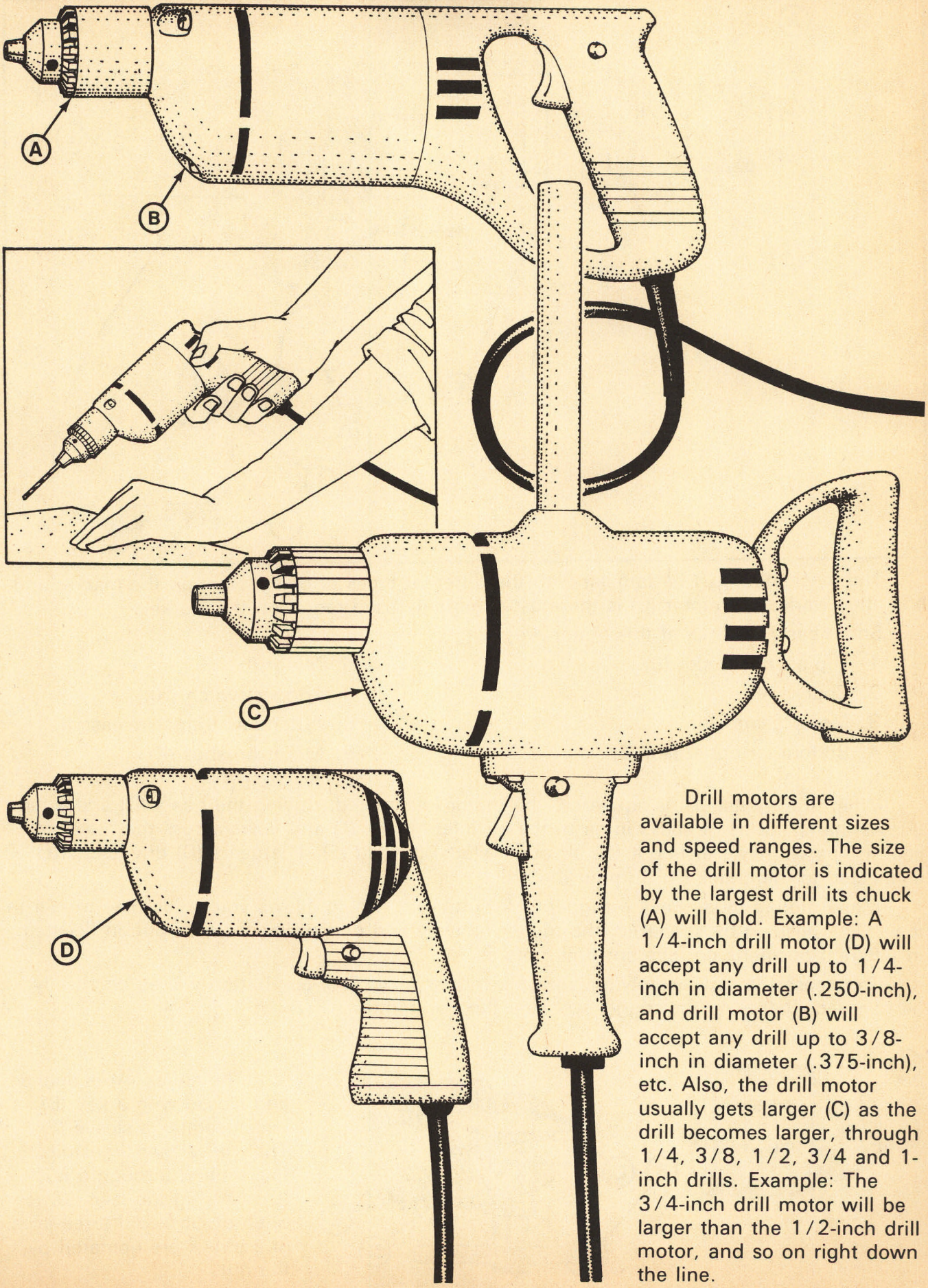


HOW TO LOCATE AND DRILL A HOLE

The center drill (C) is a drill used to help start a general-purpose drill. In order to drill a hole properly and keep it in location (position), perform the following steps:

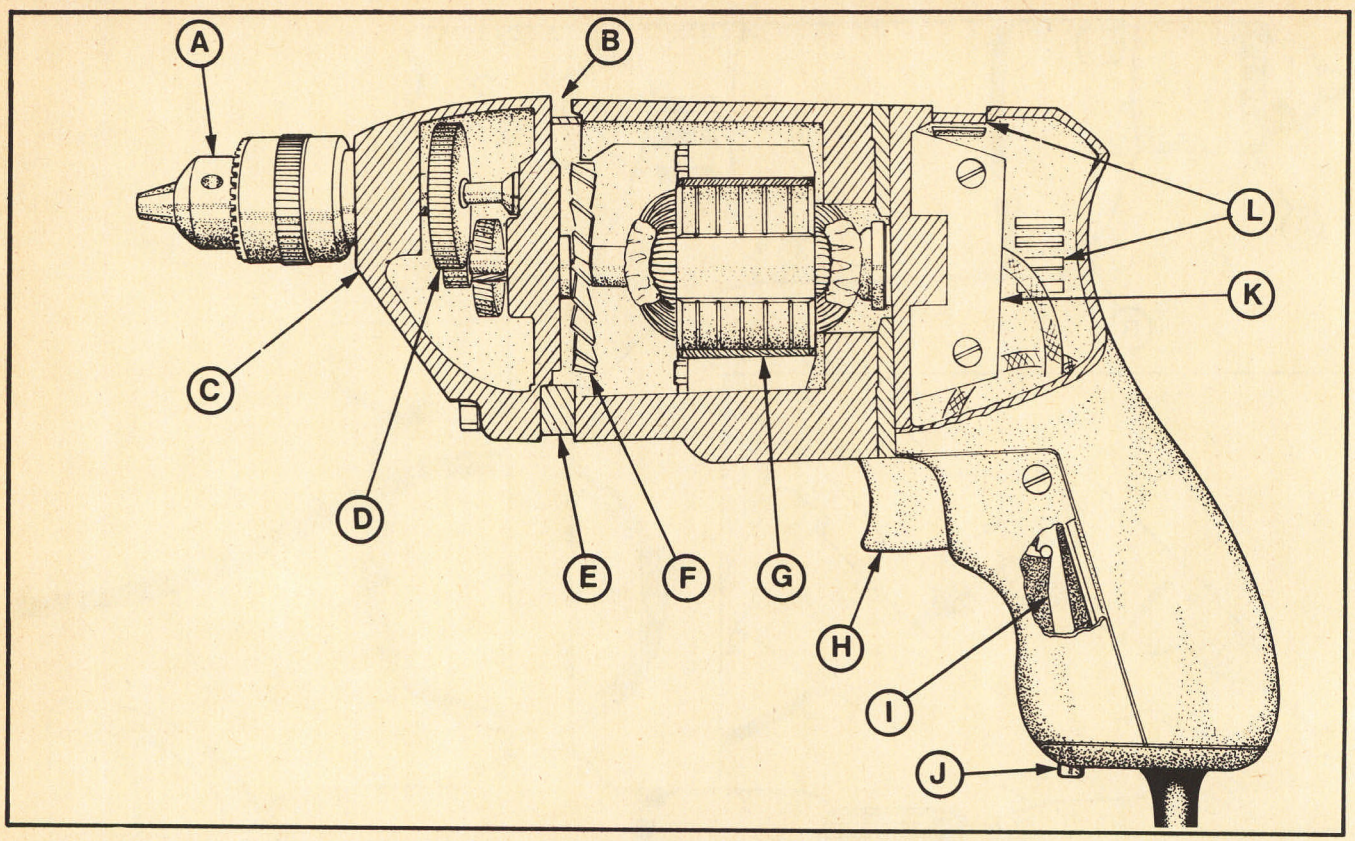
1. Using a center punch (A) and hammer, make a starting point (B) in the metal.
2. Using the center drill (C), drill into the starting mark. This will produce a centered hole (D).
3. Using a standard drill (E), drill into the centered hole (D). If the drill is ground properly, it will follow the centered hole throughout the desired depth of the hole (F).

PORTABLE ELECTRIC DRILL MOTORS



Drill motors are available in different sizes and speed ranges. The size of the drill motor is indicated by the largest drill its chuck (A) will hold. Example: A 1/4-inch drill motor (D) will accept any drill up to 1/4-inch in diameter (.250-inch), and drill motor (B) will accept any drill up to 3/8-inch in diameter (.375-inch), etc. Also, the drill motor usually gets larger (C) as the drill becomes larger, through 1/4, 3/8, 1/2, 3/4 and 1-inch drills. Example: The 3/4-inch drill motor will be larger than the 1/2-inch drill motor, and so on right down the line.

DRILL MOTORS



The mechanic must be familiar with the different types of drill motors on the market and how they work. Drill motor (C) is the most commonly used motor on the market.

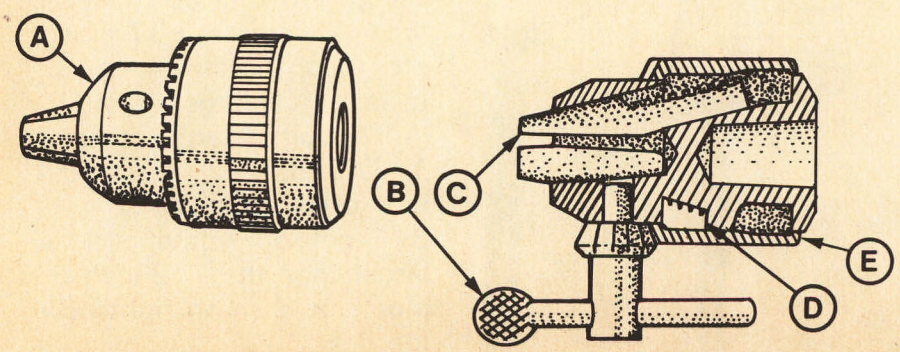
Some basic features of this motor are:

1. Top air outlet slot (B).
2. Chuck (A).
3. Motor gears (D).
4. Bottom air outlet slot (E).
5. Fan (F).
6. Motor (G).
7. Trigger switch (H).
8. Automatic trigger release (I).
9. Motor brushes (K).
10. Air inlet (L).

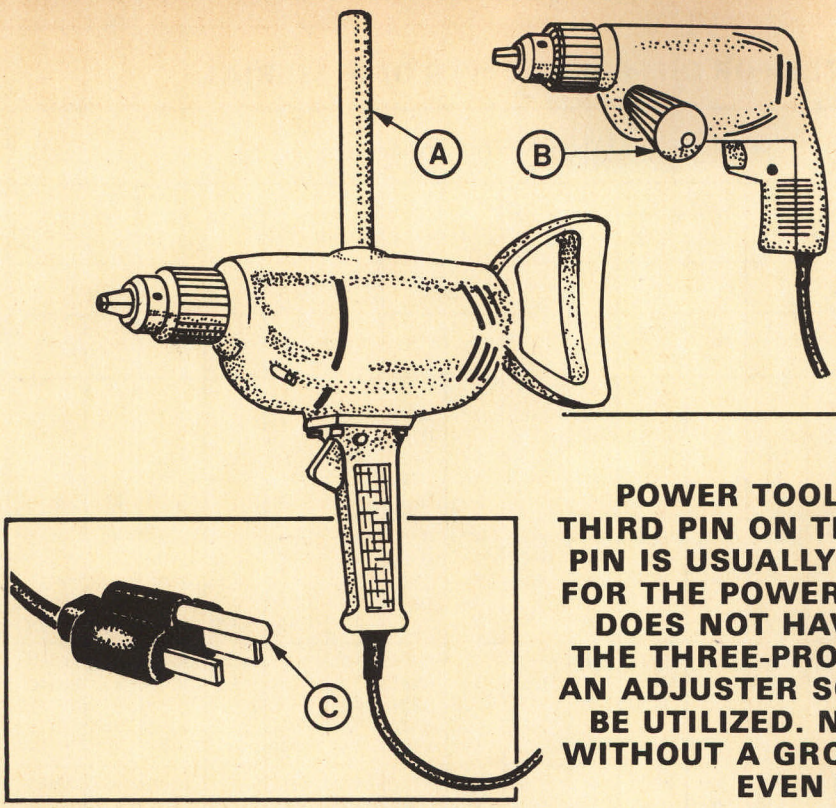
When the trigger (H) is squeezed, the motor is actuated, driving the gears (D) and a fan (F). As the fan turns, it sucks in air at the air inlet hole(s) (L) and flows across the motor to cool it. The warm air exits out the air outlet slot(s) (B) and (E). The gears (D) drive a shaft connected to the chuck (A), turning the drill.

Many motors today have a trigger lock button (J), which allows you to lock the trigger in the ''ON'' position by squeezing the trigger halfway and depressing the lock button (located in different positions on different drill motors).

To release the lock, simply squeeze the trigger fully. The lock button will automatically be released. Releasing the trigger will stop the drill motor.



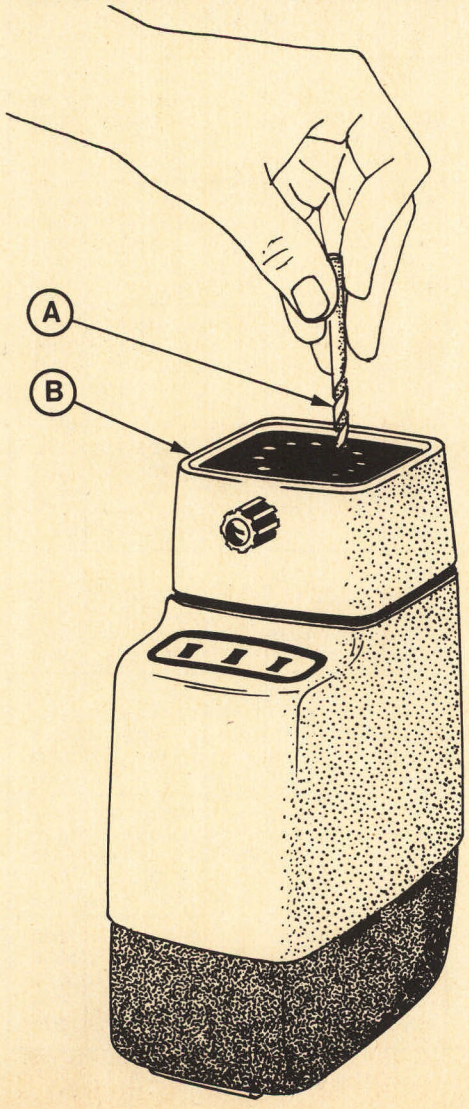
The chuck (A) is opened and closed with a key (B) which rotates a sleeve (E). The sleeve then transmits this motion through a nut (D), causing the jaws (C) to open or close. All three jaws of a chuck are operated by the nut.



Some drill motors come with handles that are removable to allow you to perform special jobs and give you more "push" on the drill motor to get through tough materials. Some handles are attached on top of the motor (A) and some at the side of the motor (B), depending upon your needs.

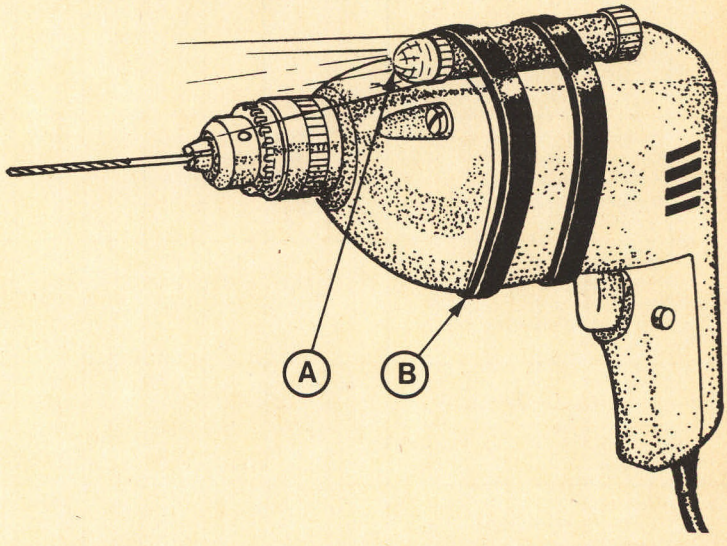
WARNING

POWER TOOLS COME EQUIPPED WITH A THIRD PIN ON THE ELECTRICAL PLUG (C). THIS PIN IS USUALLY ROUND AND IS THE GROUND FOR THE POWER TOOL. IF YOUR WALL OUTLET DOES NOT HAVE THREE HOLES TO ACCEPT THE THREE-PRONGED ELECTRICAL PLUG, USE AN ADJUSTER SO THAT THE GROUND PIN CAN BE UTILIZED. NEVER USE THE POWER TOOL WITHOUT A GROUND OR SEVERE INJURY AND EVEN DEATH CAN OCCUR.



HANDY HINTS

There is a fantastic new drill bit sharpener (B) on the market today which takes all the guesswork out of sharpening the most commonly used drills. This tool is electrically operated and will sharpen 11 different sizes of twist drill bits (A). The best thing about it, though, is that it's priced under $20.



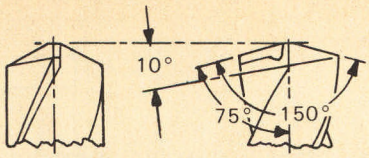
For drilling in a dark spot (such as under the car or in the engine compartment), simply place a small pen light (A) on top of the drill motor body and secure it with two strips of an old bicycle or automobile inner tube (B). The pen light is small enough not to get in the way and bright enough to shed adequate light on the subject being drilled.

RECOMMENDED HOLE (DRILL) SIZES FOR DIFFERENT TYPES OF MATERIALS

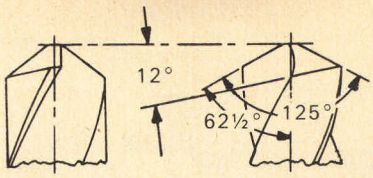
SCREW SIZE	MATERIAL	MATERIAL THICKNESS															
		Up To .047 (3/64)		.063 (1/16)		.078 (5/64) To .094 (3/32)		.109 (7/64) To .125 (1/8)		.141 (9/64)		.188 (3/16)		.250 (1/4) To .313 (5/16)		.375 (3/8) To .500 (1/2)	
		Drill		Drill		Drill		Drill		Drill		Drill		Drill		Drill	
		No.	Diam.	No.	Diam.	No.	Diam.	No.	Diam.	No.	Diam.	No.	Diam.	No.	Diam.	No.	Diam.
2-56	Sheet steel	50	.0700	50	.0700	49	.0730	48	.0760	48	.0760	47	.0785	46	.0810	46	.0810
	High tensile stainless steel	49	.0730	49	.0730	49	.0730	48	.0760	5/64	.0781	46	.0810	46	.0810	46	.0810
	Sheet aluminum	50	.0700	50	.0700	50	.0730	49	.0730	49	.0730	48	.0760	47	.0785	46	.0810
	Cast aluminum and zinc die cast									48	.0760	48	.0760	5/64	.0781	47	.0785
	Cast iron									46	.0810	46	.0810	45	.0820	45	.0820
3-48	Sheet steel	46	.0810	46	.0810	45	.0820	44	.0860	43	.0890	43	.0890	42	.0935	42	.0935
	High tensile stainless steel	45	.0820	44	.0860	44	.0860	44	.0860	43	.0890	42	.0935	42	.0935	42	.0935
	Sheet aluminum	46	.0810	46	.0810	46	.0810	45	.0820	44	.0860	43	.0890	43	.0890	42	.0935
	Cast aluminum and zinc die cast									43	.0890	43	.0890	43	.0890	43	.0890
	Cast iron									42	.0935	42	.0935	3/32	.0938	3/32	.0938
4-40	Sheet steel	43	.0890	43	.0890	42	.0935	41	.0960	40	.0980	38	.1015	37	.1040	37	.1040
	High tensile stainless steel	42	.0935	42	.0935	3/32	.0938	41	.0960	39	.0995	37	.1040	37	.1040	37	.1040
	Sheet aluminum	43	.0890	43	.0890	43	.0890	42	.0935	3/32	.0938	40	.0980	38	.1015	37	.1040
	Cast aluminum and zinc die cast									40	.0980	40	.0980	39	.0995	38	.1015
	Cast iron									37	.1040	37	.1040	36	.1065	36	.1065
5-40	Sheet steel	38	.1015	37	.1040	36	.1065	7/64	.1094	35	.1100	32	.1160	32	.1160	32	.1160
	High tensile stainless steel	37	.1040	36	.1065	36	.1065	7/64	.1094	33	.1130	32	.1160	32	.1160	32	.1160
	Sheet aluminum	38	.1015	37	.1040	37	.1040	36	.1065	36	.1065	34	.1110	33	.1130	32	.1160
	Cast aluminum and zinc die cast									35	.1100	34	.1110	33	.1130	33	.1130
	Cast iron									32	.1160	32	.1160	31	.1200	31	.1200
6-32	Sheet steel	35	.1100	34	.1110	33	.1130	32	.1160	31	.1200	1/8	.1250	30	.1285	30	.1285
	High tensile stainless steel	33	.1130	32	.1160	32	.1160	31	.1200	1/8	.1250	30	.1285	30	.1285	30	.1285
	Sheet aluminum	35	.1100	34	.1110	34	.1110	33	.1130	32	.1160	31	.1200	1/8	.1250	30	.1285
	Cast aluminum and zinc die cast									31	.1200	31	.1200	1/8	.1250	1/8	.1250
	Cast iron									30	.1285	30	.1285	30	.1285	30	.1285
8-32	Sheet steel	29	.1360	29	.1360	28	.1405	27	.1440	26	.1470	24	.1520	23	.1540	23	.1540
	High tensile stainless steel	28	.1405	28	.1405	27	.1440	27	.1440	26	.1470	23	.1540	5/32	.1562	5/32	.1562
	Sheet aluminum	29	.1360	29	.1360	29	.1360	28	.1405	27	.1440	26	.1470	25	.1495	5/32	.1562
	Cast aluminum and zinc die cast									26	.1470	26	.1470	25	.1495	24	.1520
	Cast iron									23	.1540	23	.1540	22	.1570	22	.1570
10-24	Sheet steel	24	.1520	23	.1540	22	.1570	20	.1610	19	.1660	17	.1730	16	.1770	16	.1770
	High tensile stainless steel	5/32	.1562	21	.1590	20	.1610	20	.1610	18	.1695	16	.1770	15	.1800	15	.1800
	Sheet aluminum	24	.1520	23	.1540	23	.1540	22	.1570	20	.1610	19	.1660	11/64	.1719	15	.1800
	Cast aluminum and zinc die cast									19	.1660	19	.1660	18	.1695	11/64	.1719
	Cast iron									16	.1770	16	.1770	15	.1800	15	.1800
10-32	Sheet steel	20	.1610	19	.1660	19	.1660	18	.1695	11/64	.1719	16	.1770	15	.1800	15	.1800
	High tensile stainless steel	19	.1660	19	.1660	18	.1695	18	.1695	17	.1730	15	.1800	14	.1820	14	.1820
	Sheet aluminum	20	.1610	19	.1660	19	.1660	19	.1660	18	.1695	11/64	.1719	16	.1770	14	.1820
	Cast aluminum and zinc die cast									11/64	.1719	17	.1730	17	.1730	16	.1770
	Cast iron									15	.1800	15	.1800	14	.1820	14	.1820
12-24	Sheet steel	15	.1800	15	.1800	14	.1820	3/16	.1875	11	.1910	8	.1990	13/64	.2031	13/64	.2031
	High tensile stainless steel	14	.1820	13	.1850	3/16	.1875	12	.1890	9	.1960	7	.2010	5	.2055	5	.2055
	Sheet aluminum	15	.1800	15	.1800	15	.1800	13	.1850	3/16	.1875	11	.1910	8	.1990	5	.2055
	Cast aluminum and zinc die cast									11	.1910	10	.1935	9	.1960	8	.1990
	Cast iron									7	.2010	13/64	.2031	5	.2055	5	.2055
¼-20	Sheet steel	5	.2055	4	.2090	4	.2090	7/32	.2188	2	.2210	1	.2280	A	.2340	A	.2340
	High tensile stainless steel	4	.2090	3	.2130	3	.2130	7/32	.2188	1	.2280	A	.2340	15/64	.2344	15/64	.2344
	Sheet aluminum	5	.2055	5	.2055	5	.2055	3	.2130	3	.2130	2	.2210	1	.2280	15/64	.2344
	Cast aluminum and zinc die cast									2	.2210	2	.2210	1	.2280	1	.2280
	Cast iron									A	.2340	15/64	.2344	B	.2380	B	.2380
5/16-18	Sheet steel			17/64	.2656	I	.2720	J	.2770	K	.2810	L	.2900	M	.2950	M	.2950
	High tensile stainless steel			1	.2720	J	.2770	J	.2770	9/32	.2812	M	.2950	19/64	.2969	19/64	.2969
	Sheet aluminum									I	.2720	K	.2810	L	.2900	19/64	.2969
	Cast aluminum and zinc die cast									K	.2810	9/32	.2812	L	.2900	L	.2900
	Cast iron									M	.2950	M	.2950	19/64	.2969	19/64	.2969
3/8-16	Sheet steel			P	.3230	21/64	.3281	Q	.3320	R	.3390	S	.3480	T	.3580	T	.3580
	High tensile stainless steel			21/64	.3281	Q	.3320	Q	.3320	11/32	.3438	S	.3480	T	.3580	T	.3580
	Sheet aluminum									Q	.3320	R	.3390	S	.3480	T	.3580
	Cast aluminum and zinc die cast									R	.3390	R	.3390	11/32	.3438	S	.3480
	Cast iron									S	.3480	T	.3580	23/64	.3594	23/64	.3594

SLIGHTLY LARGER HOLE SIZES ARE RECOMMENDED FOR FINE THREAD SERIES. CHECK HOLE DEPTH SPECIFICATIONS WITH CAUTION—CHECK POINT LENGTH TO ASSURE SUFFICIENT TAPPED HOLDING POWER.

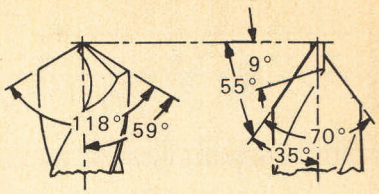
RECOMMENDED DRILL POINTS FOR DIFFERENT TYPES OF MATERIALS



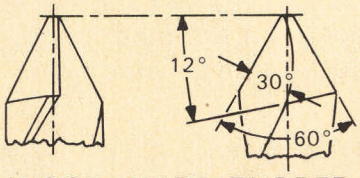
STEEL RAILS (7% TO 13% MANGANESE) and HARD MATERIALS



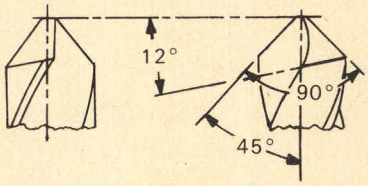
HEAT-TREATED STEELS, DROP FORGINGS and CONNECTING RODS



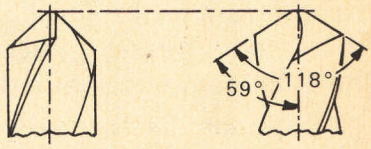
CRANKSHAFT and DEEP HOLE DRILLING



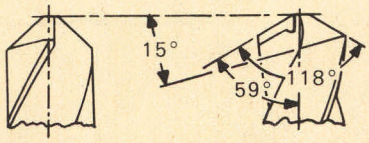
WOOD, HARD RUBBER and FIBER



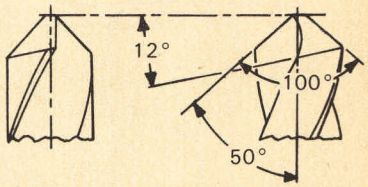
CAST IRON, HARD RUBBER, FIBER, ALUMINUM ALLOYS and DIE CASTINGS



PLASTIC and MOLDED MATERIALS



BRASS AND SOFT BRONZE

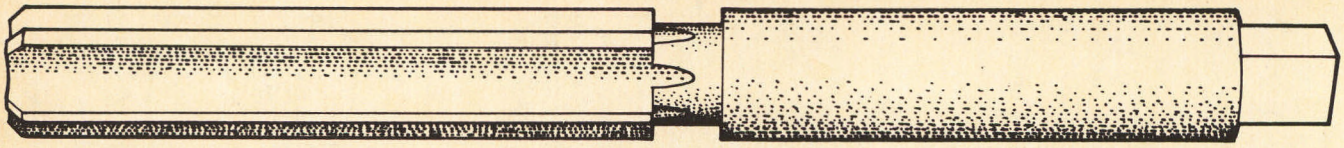


COPPER and SOME COPPER ALLOYS

DRILL TROUBLE CHART

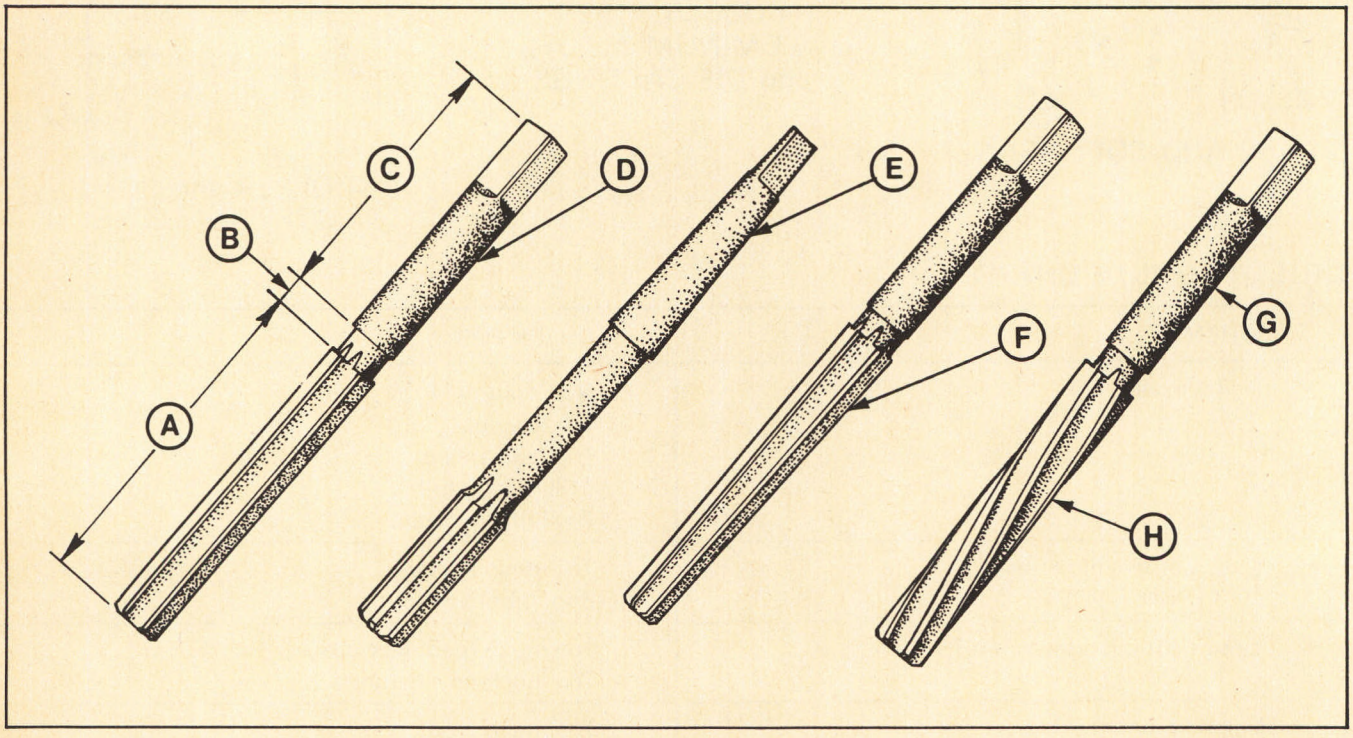
WHEN:	CHECK FOR:
Drill breaks	Non-rigidity Too low speed Too high speed Dullness of drill Too little lip clearance
Outer corners of cutting edges break down	Too much speed Poor lubrication
Lips or cutting edges chip	Too much feed pressure Too much lip clearance
Chipping or checking occurs on a high-speed drill	Too much feed pressure Too rapid heating and cooling of tool while drilling or grinding
Chips change in nature during drilling	Change in condition of drill, such as dulling, chipping, etc.
Hole drills out too large	Unequal angle or length of the cutting edges Drill loose in chuck
One lip only is cutting	Unequal angle or length of the cutting lips
Drill splits up center	Too much feed pressure Too little lip clearance
Hole drills out rough	Dullness of drill Poorly ground drill Poor lubrication Wrong lubricant Too much feed pressure Improper setup

REAMERS



It is seldom possible to produce a hole that is perfectly straight and exactly the same diameter as a drill. For certain types of work, slight inaccuracies in producing holes are of little importance and the finished holes produced with drills are satisfactory. On the other hand, when a high degree of accuracy is required, other means must be used to finish the holes. The most common method of doing this is by reaming.

When reamers are used for the accurate sizing of holes, the material is first drilled to a few thousandths of an inch under the desired size and then finished to the exact diameter with a reamer.



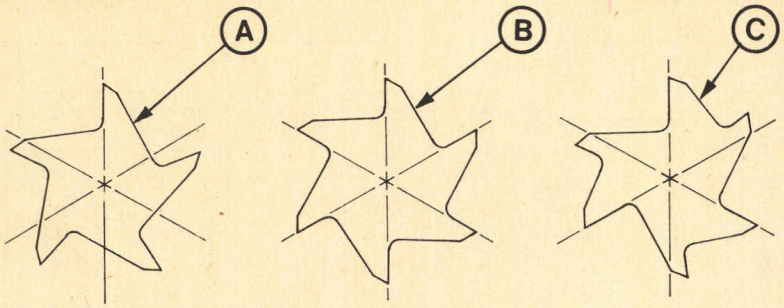
Reamers are classified into two types, the hand reamer (D) and the machine reamer (E).

As the name implies, the hand reamer (D) is used by hand. The shank (C) is straight and has a square tang so it can be held and operated with a wrench (usually a tap handle). Reamer (E) has a tapered shank and is used in power machines such as a drill press or lathe. The hand reamer can always be identified by its square tang. The small area (B) is called the neck and (A) is the body of the reamer. Hand reamers are available with tapered flutes (F) or spiral flutes (H).

The flutes of a reamer are similar to those used in drills. They extend along the length of the body between the blades, which form the cutting edges of the tool, and provide chip space when cutting. The shank (C) of a straight reamer is always one or two thousandths of an inch smaller in diameter than the body (A) of the reamer, so the reamer can pass completely through the holes it makes without binding on the shank.

The spiral reamer (G) yields the best results. This reamer will not chatter (vibrate) during the reaming operation. The straight-fluted reamer (D) will occasionally chatter and produce an out-of-round hole by gouging out pieces of metal along the length of the hole.

FLUTE
END VIEWS

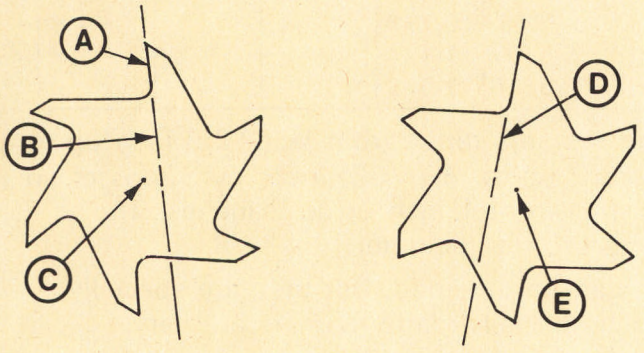


Chatter can sometimes be eliminated by using a reamer with an odd number of flutes (A). The odd number of cutting edges means that none of them is directly opposite another, as they are in reamer (B), which has an even number of flutes.

Using a reamer with *uneven spacing* (C) of the flutes also prevents one cutting edge from being directly opposite another, thus eliminating chatter.

Using a reamer with an odd number of flutes or uneven spacing has one disadvantage: The reamer cannot be checked for size with a micrometer. The dimension obtained would not be the true diameter of the reamer. Such reamers can be checked for size only by testing them in a hole of a known diameter.

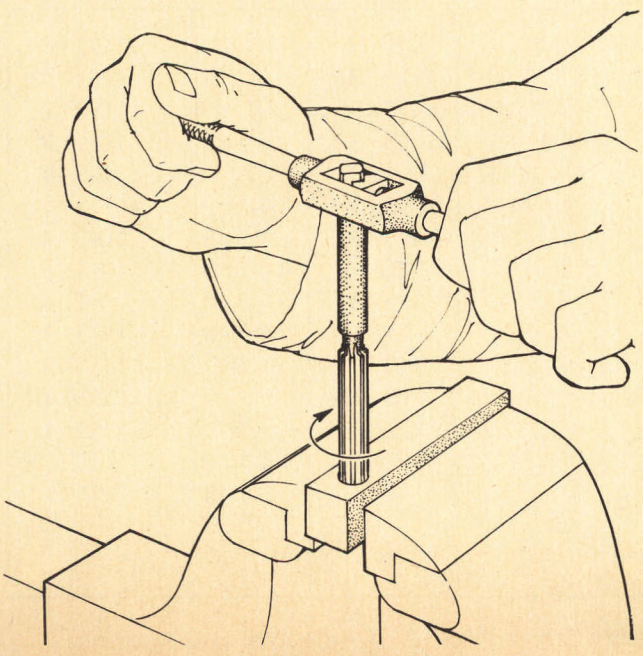
REAMER POSITIVE RAKE AND NEGATIVE RAKE



When a reamer is to be used in soft metal such as aluminum, the tooth (A) is cut on a line (B) back of the reamer center point (C) to produce what is known as a *positive* rake angle. The cutting edge formed is quite sharp and enables the reamer to cut freely.

In *negative* rake angle, the line (D) of the cutting edge falls ahead of the reamer center point (E). This type of construction provides a strong cutting edge and is used for cutting very hard steel.

The negative-reamer rake is also used for removing brass, even though it is a soft metal, because the negative rake prevents the tool from becoming clogged or gouging into the work. This rake produces a scraping rather than a cutting action; the cutting edges do not bite deeply into the metal.



NUMBER OF FLUTES IN HAND REAMERS	
DIAMETER	
1/8" to 7/32"	4 flutes
1/4" to 15/32"	6 flutes
1/2" to 1-1/4"	8 flutes
1-9/32" to 1-23/32"	10 flutes
1-3/4" to 2-7/32"	12 flutes
2-1/4" to 2-3/4"	14 flutes
2-25/32" to 3"	16 flutes

The number of flutes to be cut in a reamer depends on the diameter of the body. The table shows the number of flutes recommended for the various diameters of hand reamers.

HAND REAMER SIZE CHARTS

STRAIGHT HAND REAMER SIZES											
Diameter (inches)	Length of Flute (inches)	Length Overall (inches)	Diameter (inches)	Length of Flute (inches)	Length Overall (inches)	Diameter (inches)	Length of Flute (inches)	Length Overall (inches)	Diameter (inches)	Length of Flute (inches)	Length Overall (inches)
1/8	1-1/2	3	25/64	2-5/8	5-1/4	21/32	3-11/16	7-3/8	1-3/16	6	12
9/64	1-5/8	3-1/4	13/32	2-5/8	5-1/4	43/64	3-7/8	7-3/4	1-1/4	6-1/8	12-1/4
5/32	1-5/8	3-1/4	27/64	2-3/4	5-1/2	11/16	3-7/8	7-3/4	1-5/16	6-1/4	12-1/2
11/64	1-3/4	3-1/2	7/16	2-3/4	5-1/2	45/64	4-1/16	8-1/8	1-3/8	6-5/16	12-5/8
3/16	1-3/4	3-1/2	29/64	2-7/8	5-3/4	23/32	4-1/16	8-1/8	1-7/16	6-7/16	12-7/8
13/64	1-7/8	3-3/4	15/32	2-7/8	5-3/4	47/64	4-3/16	8-3/8	1-1/2	6-1/2	13
7/32	1-7/8	3-3/4	31/64	3	6	3/4	4-3/16	8-3/8	1-9/16	6-1/2	13
15/64	2	4	1/2	3	6	25/32	4-3/8	8-3/4	1-5/8	6-1/2	13
1/4	2	4	33/64	3-1/8	6-1/4	13/16	4-9/16	9-1/8	1-11/16	6-3/4	13-1/2
17/64	2-1/8	4-1/4	17/32	3-1/8	6-1/4	27/32	4-11/16	9-3/8	1-3/4	6-3/4	13-1/2
9/32	2-1/8	4-1/4	35/64	3-1/4	6-1/2	7/8	4-7/8	9-3/4	1-13/16	6-3/4	13-1/2
19/64	2-1/4	4-1/2	9/16	3-1/4	6-1/2	29/32	5	10	1-7/8	7	14
5/16	2-1/4	4-1/2	37/64	3-3/8	6-3/4	15/16	5-1/8	10-1/4	1-15/16	7	14
21/64	2-3/8	4-3/4	19/32	3-3/8	6-3/4	31/32	5-5/16	10-5/8	2	7	14
11/32	2-3/8	4-3/4	39/64	3-1/2	7	1	5-7/16	10-7/8			
23/64	2-1/2	5	5/8	3-1/2	7	1-1/16	5-5/8	11-1/4			
3/8	2-1/2	5	41/64	3-11/16	7-3/8	1-1/8	5-13/16	11-5/8			

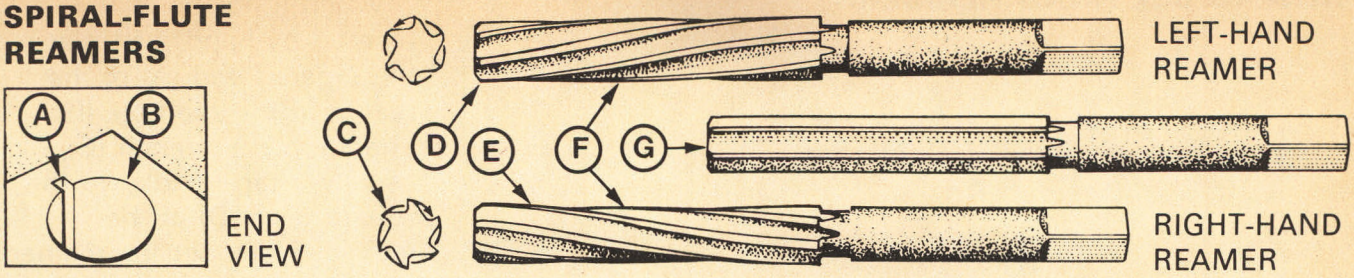
As seen in the chart above, standard sizes of hand reamers range from ⅛ (.125) inch up to 2 inches. The sizes increase by 64ths of an inch from 0 up to ¾ (.750) inch, by 32nds of an inch from ¾-inch up to 1 inch, and by 16ths of an inch from 1 inch up to 2 inches. The length of the reamer, of course, increases in proportion to the diameter.

Reamer sizes other than those shown in the chart can be obtained, but they are specially made according to the customer's specifications. Such specially-made reamers are very expensive, so the use of odd sizes is avoided whenever possible.

HAND EXPANSION REAMER SIZES								
Diameter (inches)	Length of Flute (inches)	Length Overall (inches)	Diameter (inches)	Length of Flute (inches)	Length Overall (inches)	Diameter (inches)	Length of Flute (inches)	Length Overall (inches)
1/4	1-1/2	3-3/4	25/32	3	6-7/8	1-5/16	4-7/16	10-1/8
9/32	1-5/8	3-7/8	13/16	3-1/16	7-1/8	1-11/32	4-1/2	10-1/4
5/16	1-13/16	4	27/32	3-1/4	7-3/8	1-3/8	4-7/16	10-3/8
11/32	1-13/16	4-1/8	7/8	3-3/8	7-9/16	1-13/32	4-1/2	10-1/2
3/8	1-7/8	4-1/4	29/32	3-1/2	7-13/16	1-7/16	4-7/16	10-5/8
13/32	1-7/8	4-3/8	15/16	3-5/8	8-1/16	1-15/32	4-1/2	10-11/1
7/16	1-7/8	4-1/2	31/32	3-13/16	8-9/32	1-1/2	4-1/2	10-3/4
15/32	1-7/8	4-3/4	1	3-7/8	8-1/2	1-9/16	4-5/8	11-1/8
1/2	1-7/8	5	1-1/32	4	8-3/4	1-5/8	4-3/4	11-1/4
17/32	1-15/16	5-3/16	1-1/16	4-1/16	9	1-11/16	4-7/8	11-3/8
9/16	2-1/16	5-3/8	1-3/32	4-1/8	9-1/8	1-3/4	5	11-1/2
19/32	2-3/16	5-9/16	1-1/8	4-1/8	9-1/4	1-13/16	5-1/8	11-3/4
5/8	2-5/16	5-3/4	1-5/32	4-3/16	9-13/32	1-7/8	5	11-3/4
21/32	2-1/2	6	1-3/16	4-3/16	9-9/16	1-15/16	5-1/8	12
11/16	2-11/16	6-1/4	1-7/32	4-1/4	9-23/32	2	5-1/8	12-1/4
23/32	2-3/4	6-7/16	1-1/4	4-1/4	9-7/8			
3/4	2-13/16	6-5/8	1-9/32	4-3/8	10			

This chart gives the sizes of hand expansion reamers from ¼ (.250) inch up to 2 inches.

SPIRAL-FLUTE REAMERS



A much superior cutting action is obtained with spiral-flute reamers (F), since the angle of the cutting edge to the work produces a shearing cut and reduces the tendency of the tool to chatter. Also, in certain instances a hole (B) to be reamed may have had a keyway (A) machined in it. In such a case it would be impossible to ream the hole with a straight-flute reamer (G), because the cutting edges of the reamer would fall into the keyway (A), jamming or breaking the reamer. A spiral-flute reamer (F), however, permits its cutting edges to pass over a keyway without difficulty.

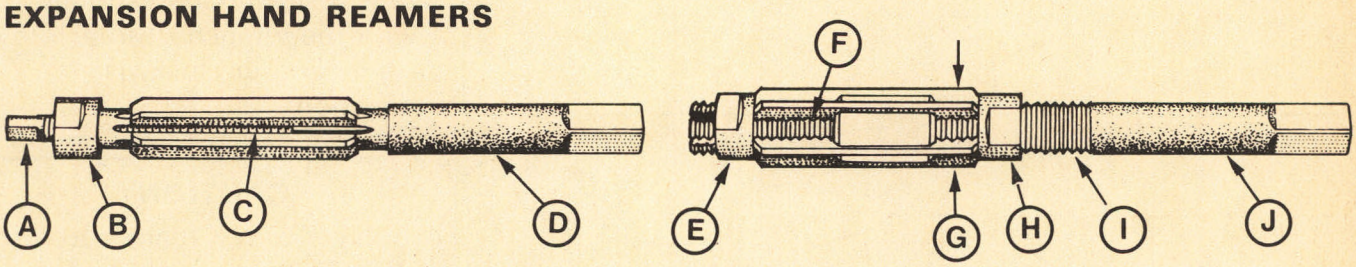
Spiral-flute reamers are made with either a right- (E) or left-hand (D) spiral to adapt to different types of work.

A right-hand spiral (E) turns to the right, or clockwise, when viewed from the end (C) of the reamer; a left-hand spiral (D) turns in the opposite direction.

ALWAYS operate the reamer in a right-hand or clockwise direction, whether it has a right- or left-hand spiral.

A left-hand spiral is best suited for most types of work, since the direction of the spiral resists the feed of the reamer into the work—a desirable feature. A right-hand spiral tends to draw the reamer into the work so that it advances too rapidly and causes the cutting edges to take more of a cut than they can stand.

EXPANSION HAND REAMERS

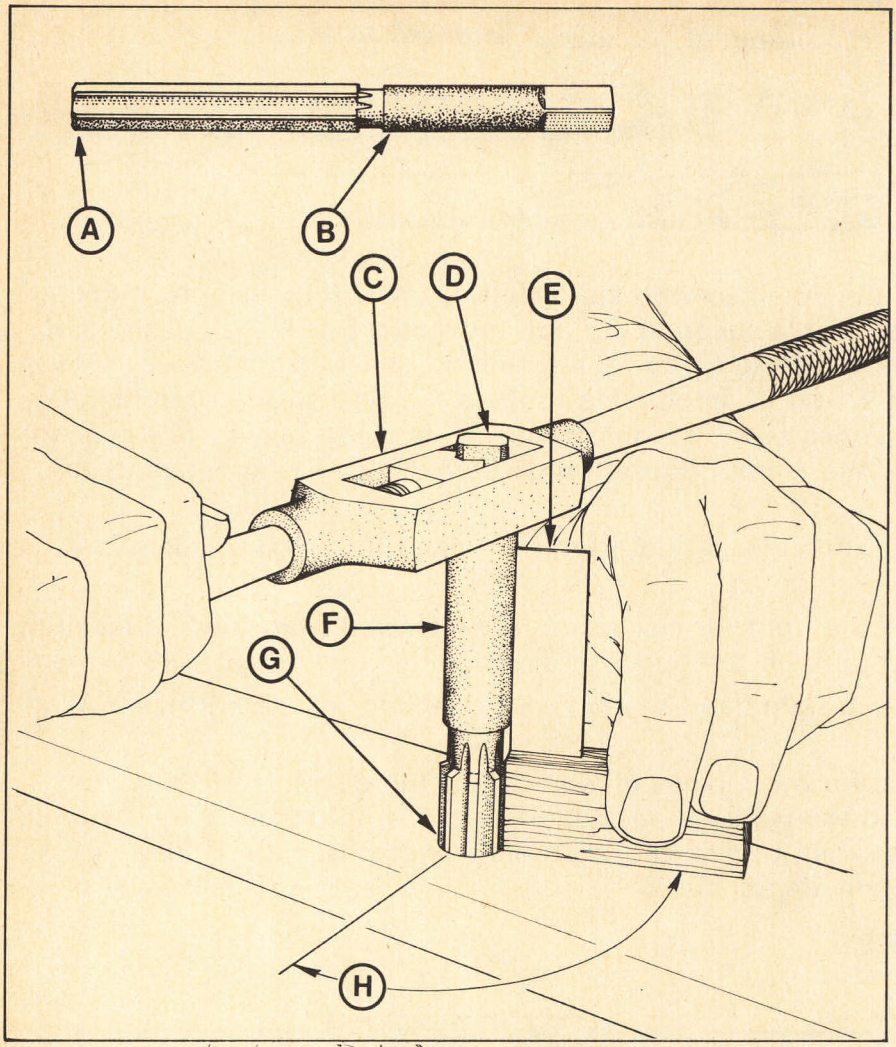


Expansion hand reamers are used where the fitting of parts in a final assembly is required. The expansion reamer (D) is made of a solid piece of Tool Steel and has from three to six slots (C) cut in the bottoms of the flutes around the body. These slots extend into the hollow center of the tool, which is drilled and reamed on a slight taper. A screw (A) with a tapered end screws into the body (B) of the reamer. When the screw is forced against the inner, tapered portion, it pushes out or expands the blades of the reamer.

The second type of expansion reamer (J) is the adjustable blade reamer. The body of the reamer is threaded (I) throughout its entire length. Tapered slots to receive the blades are also machined on the reamer body (G). The blades are tapered along one edge to correspond with the tapered slots. Once in position, the cutting edges of blades opposite each other are parallel.

The diameter of the reamer blades (G) is set by means of the adjusting nuts (E, H), which also hold the blades in the slots (F). By loosening one nut and tightening the other, the blades can be moved in either direction. Moving the blades in the direction of the threaded shank (I) expands them. One complete revolution of the adjusting nuts (E, H) expands or contracts the reamer approximately four thousandths of an inch. The expansion reamer is used quite frequently by automotive mechanics. It is useful in assembling parts where bushings must be reamed to suit the size of pins, spindles, etc. Each reamer has sufficient expansion to increase its diameter to the next larger size reamer.

HOW TO USE HAND REAMERS

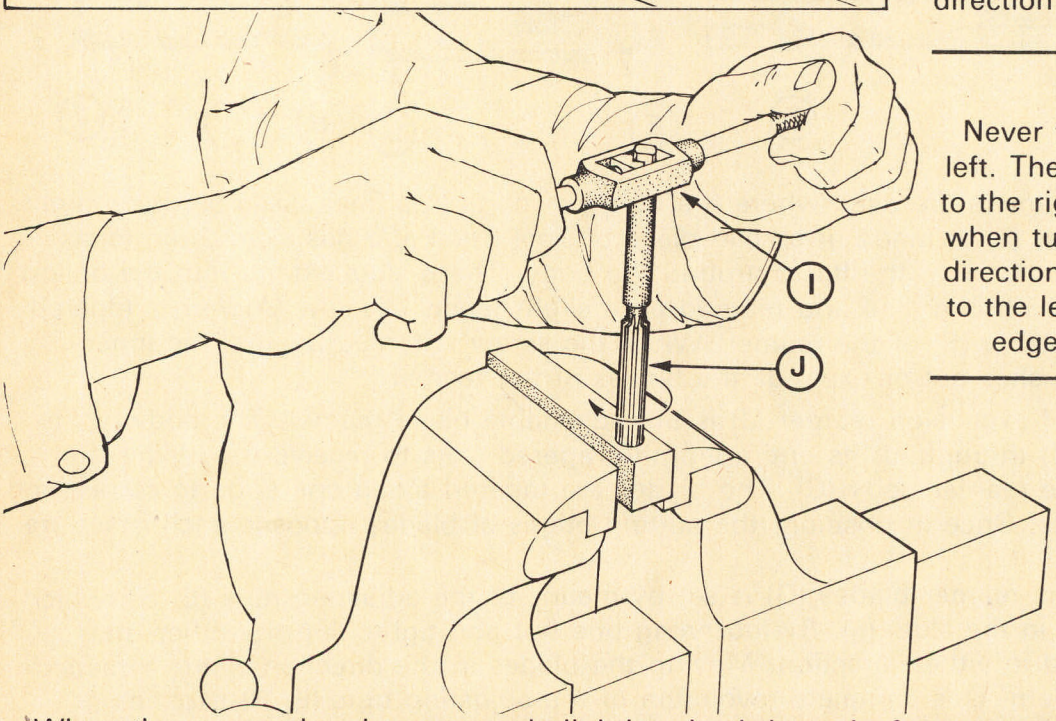


When a hole is to be reamed by hand, first place the tapered end (A) of the reamer (B) in the hole (G). Then apply a wrench (C), usually a tap handle, to the square tang (D) of the reamer. Next, set the reamer square with the work (at right angles to the material). If the top of the work is flat, place a square (E) against the side of the reamer. Check the reamer position again, 90° (H) from the first position. The blades of the reamer should be exactly parallel with the blade of the square (E) in each position. If the top of the work is not flat, the reamer must be aligned to the hole by sight. In this case it is sighted from two positions, 90° apart.

After the reamer (J) has been aligned to the hole, turn it slowly and carefully with the wrench (I) in a right-hand or clockwise direction.

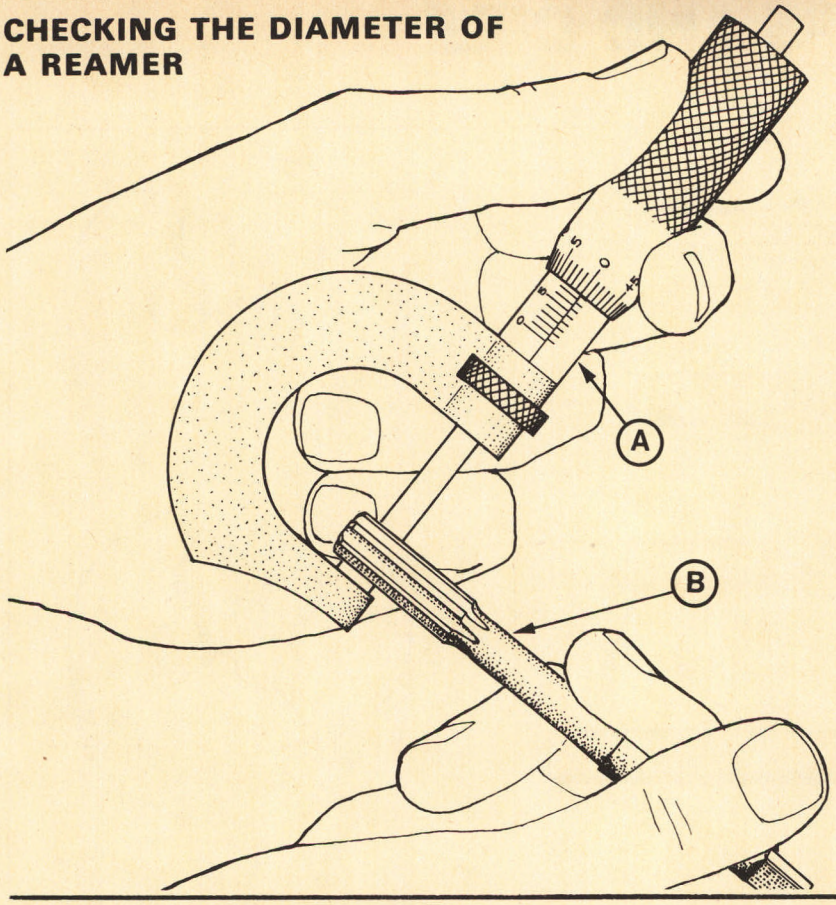
CAUTION

Never turn a reamer to the left. They are made to turn to the right and will not cut when turned in the reverse direction. Turning a reamer to the left dulls the cutting edges of the blades.



When the reamer has been turned slightly, check it again from two positions 90° apart to be sure it is starting straight. Continue in this manner, applying an even pressure to the wrench (I) with both hands so the reamer will not move to one side while turning it. Allowing the reamer to move to one side will result in an oversized hole.

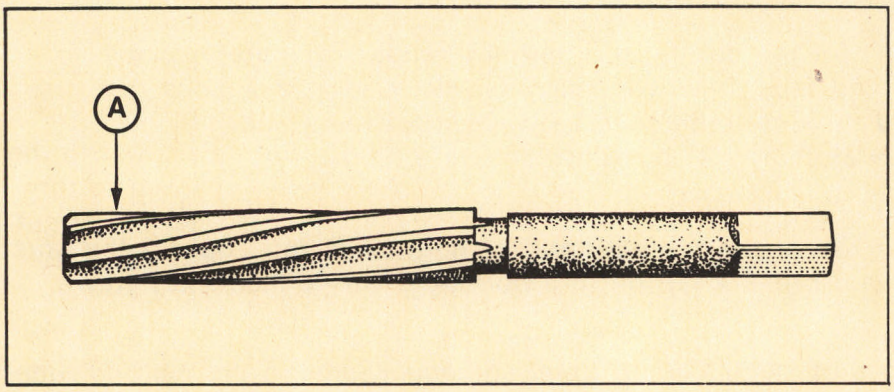
CHECKING THE DIAMETER OF A REAMER



When the size of the hole is important, the operator must check the reamer (B) *personally* with a micrometer (A). It may be wise to try the reamer first in a practice hole to be sure it is cutting to size. It is too late to check the reamer after a hole has been cut oversize, and the operator alone is responsible for the result.

When reaming steel, cutting oil should be used to produce a smooth hole. Cast iron is usually reamed dry, although some machinists use a small amount of kerosene or turpentine on the reamer blades if the material is very hard. No lubricant should ever be used with soft cast iron.

CARE OF REAMERS



The quality of the finish and accuracy of holes produced, as well as the useful life of the reamer, depend to a very large extent on the care the tool receives both in operation and in storage. The smallest burr on the cutting edge (A) of a reamer will produce a rough hole; therefore a reamer must always be inspected by feeling along the cutting edge. If any burrs are found, they must be removed with an oilstone.

Always use a lubricant such as lard oil when reaming steel. Lard oil is also used in reaming aluminum and monel metal. Oil should be applied when working brass, bronze and copper, though bronze is sometimes reamed dry. Lubricant is not generally used in reaming cast iron.

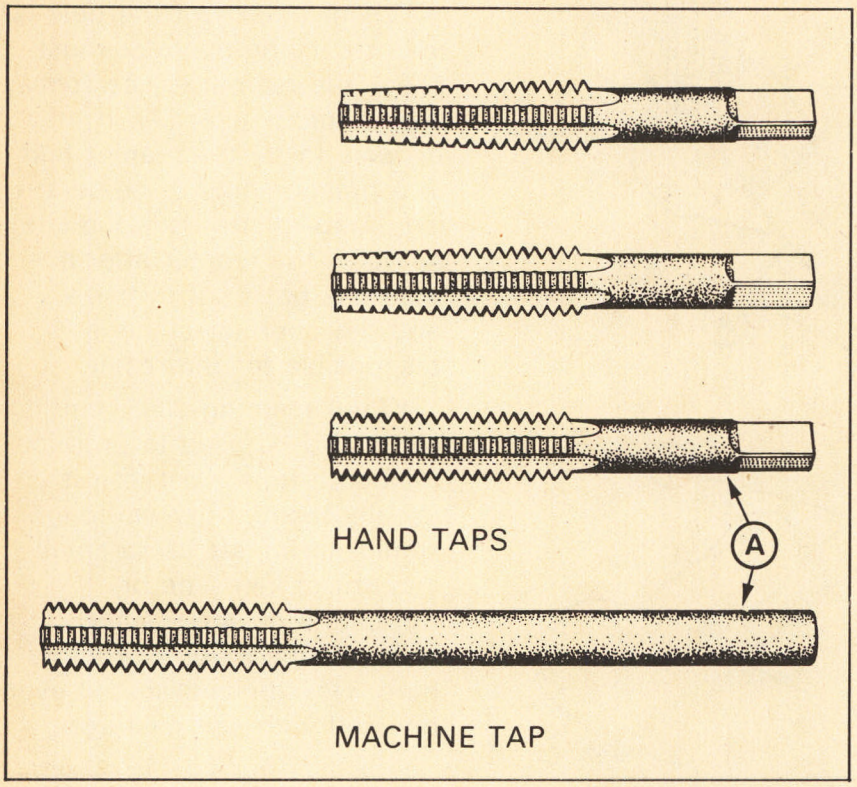
Never start a reamer on an uneven surface. The reamer will tend to drift toward the point of least resistance. This not only produces a hole that is out-of-round and otherwise lacking in trueness, but also subjects the reamer to severe strains.

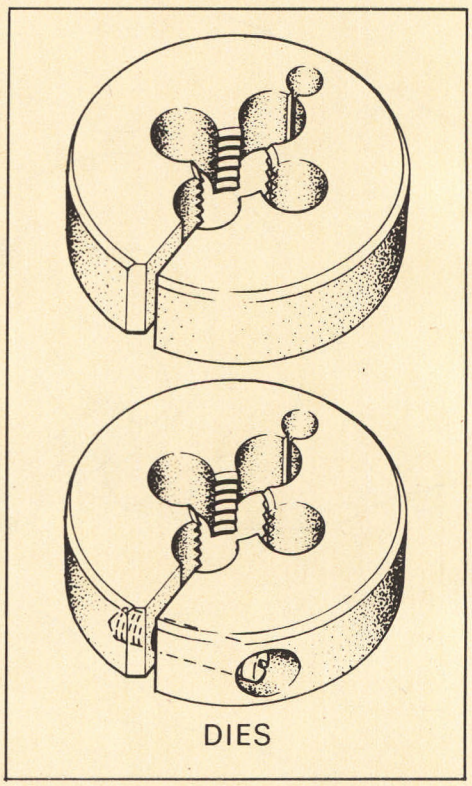
Never stack reamers in bins or tool boxes without some separating layer of cardboard or wood. The edges are so hard and sharp that even a light impact against each other or some other hard object will chip the edges. Individual cardboard or plastic tubes make excellent holders for reamers in storage.

See that reamers are properly coated with oil when not in use to prevent rusting at the cutting edges. Even a small rust spot will leave a pit or nick.

If careful attention is given to the above precautions, your reamer will have a long and useful life.

TAPS AND DIES





The tap and die are tools for cutting internal and external threads. The tap cuts threads for a screw or bolt by cutting threads in a hole drilled in some material (usually metal). The die cuts threads on a rod or bolt to accept a nut.

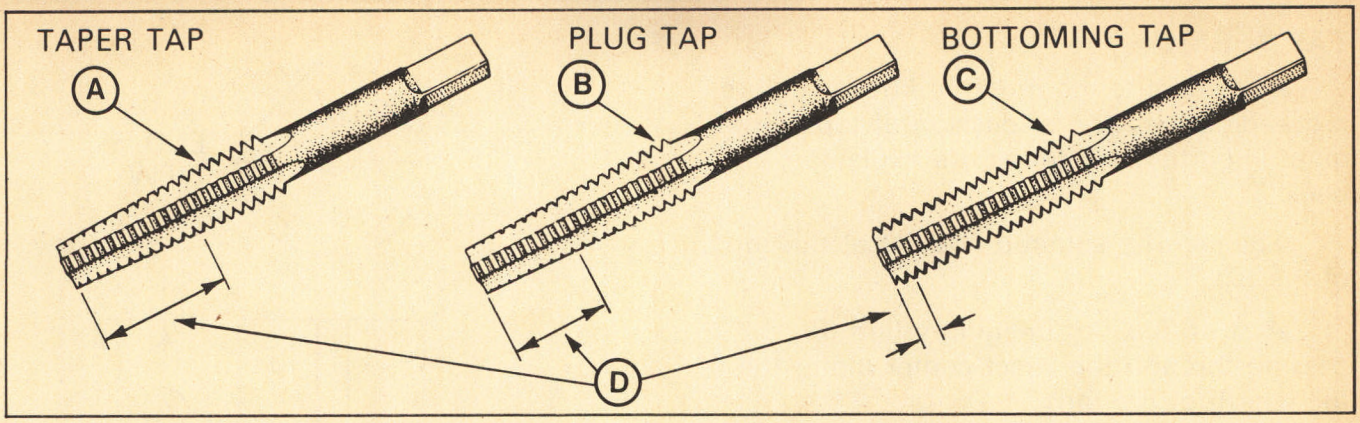
The tap is a formed tool used for the cutting of internal threads. Taps are available in both hand and machine types. Hand taps, however, may also be used in machines and operated under power. Practically the only difference between most hand and machine-operated taps is the type of shank (A) by which they are held.

Taps are highly tempered for strength, thus making them very brittle. We will discuss later on in this section the proper use of the tap with and without lubricants, but for the time being, just a word of caution: If you break a tap off in a hole, it is very difficult to remove, so handle with care.

Taps are made from two types of steel, *Carbon Steel* and *High-Speed Steel. Carbon Steel* is simply purified iron to which carbon has been added to produce hardness. This steel is satisfactory in a tap where high cutting temperatures are not encountered and where the material being tapped is not of an abrasive nature.

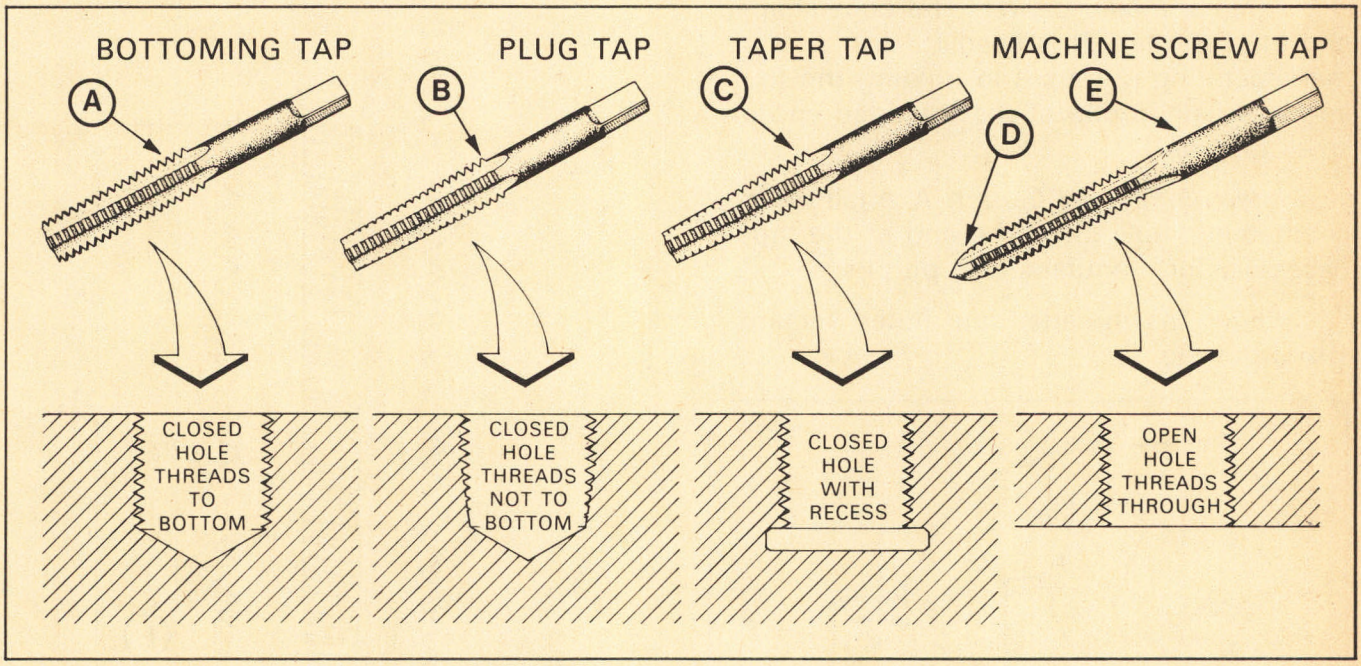
High-Speed Steel is a combination of iron, carbon, tungsten, chromium, vanadium, manganese, molybdenum and sometimes cobalt. These elements provide the steel with the properties of hardness and toughness and the ability to withstand high cutting temperatures and resist wear. *High-Speed Steel* taps will operate at temperatures up to 1100° F without the cutting edges breaking down. This is approximately 700° F more heat than the Carbon Steel tool will stand.

The most common taps used by mechanics today that allow you to perform any job are shown above. The tap threads most commonly used in the automotive industry are the National Coarse (NC) and National Fine (NF) threads, but you should be aware of two other types of threads. They are the National Pipe Thread (NPT) and the Special Thread (NS or national extra fine thread).



The bottoming, plug and taper taps shown here are identical in the size of the thread and the length of the tap. Their only difference is in the chamfered (tapered) threaded portion (D) at the end of the tap.

When the thread must be cut to the very bottom of a blind hole, all three taps are generally used; that is, the thread is started with the taper tap (A), cut further into the hole with the plug tap (B) and finished to the bottom of the hole with the bottoming tap (C). The taper tap (A) has the longest chamfer of all the taps and usually extends approximately 10 threads back from the point. The plug tap (B) has approximately a five-thread chamfer, while the bottoming tap has a one-thread chamfer.



The bottoming tap (A) is used when it is necessary to cut full threads to the bottom of a closed hole (a hole which has not been drilled through the material). Plug taps (B) or bottoming taps should *never* be used to *start* a thread.

The plug tap (B) is used when one end of the hole is closed and a full thread is not required at the bottom of the hole.

The taper tap (C) is used to start all threads and may be used to finish the tapping operation when the tap can be run entirely through the material.

The machine screw tap (E) is used for fine-thread, small-diameter tapping operations. The cone-shaped end (D) of the machine screw tap is made that way for manufacturing purposes and is usually found at the threaded end of small taps only. The machine screw tap also comes in the bottoming tap, plug tap and taper tap.

TAPS AND DIES

TAP TERMS

Additional terms must be known before proceeding with the discussion of taps. The more important tap terms are explained here.

Square: The squared end (A) at the top of the tap.

Axis of Tap: An imaginary line (B) passing through the exact center along the full length of the tap.

Shank: The part (C) behind the threaded and fluted section (D) of the tap.

Chamfer: The tapered outside diameter (E) at the front end of the threaded section.

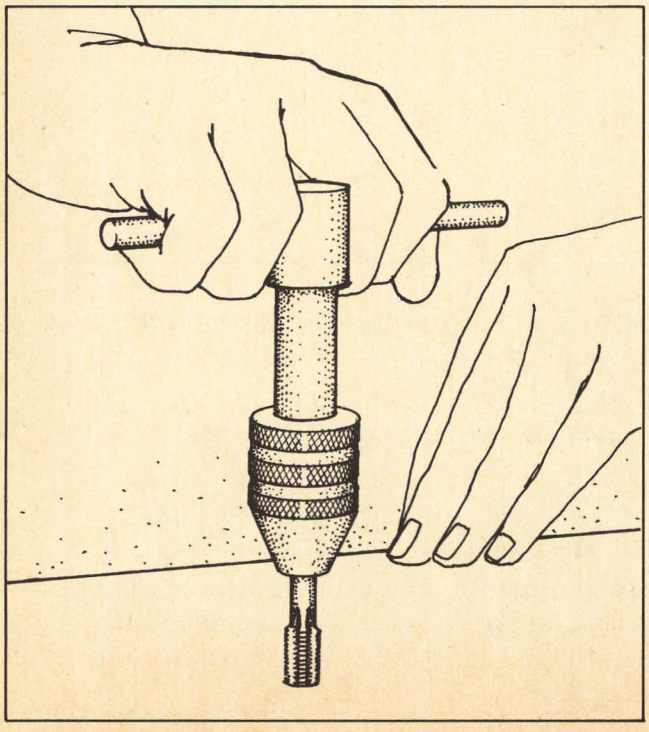
Cutting Face: The front of the land (F) of the threaded section.

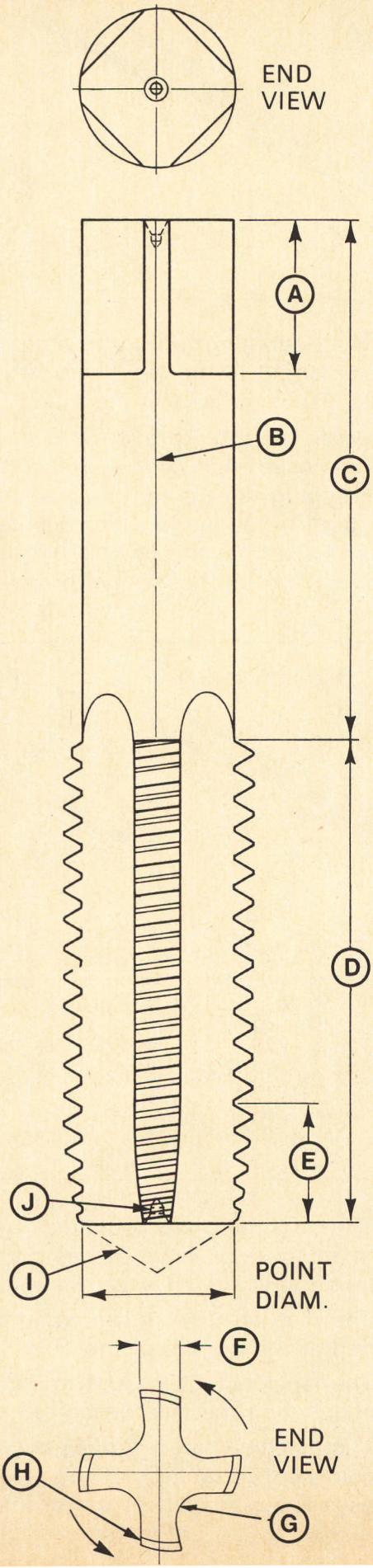
Flute: The four grooves or flutes (G) provided for the cutting faces (H) of the threads for chip passage and lubrication.

External (Male) Center: The cone-shaped end (I) of the tap. It is used for manufacturing purposes in holding the tap and is usually found at the threaded end of small taps only.

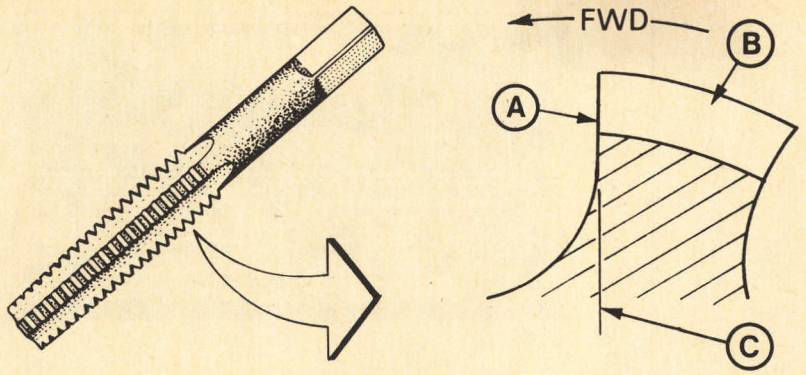
Internal (Female) Center: A small drilled, countersunk hole (J) at the end of the tap necessary for manufacturing purposes.

Body: The threaded and fluted section (D) of the tap.

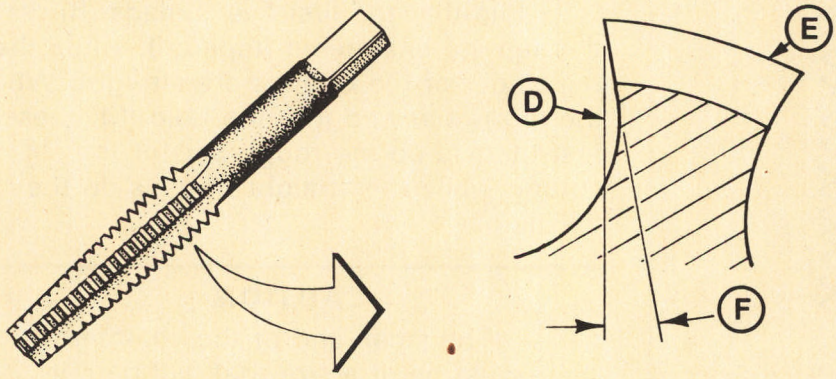




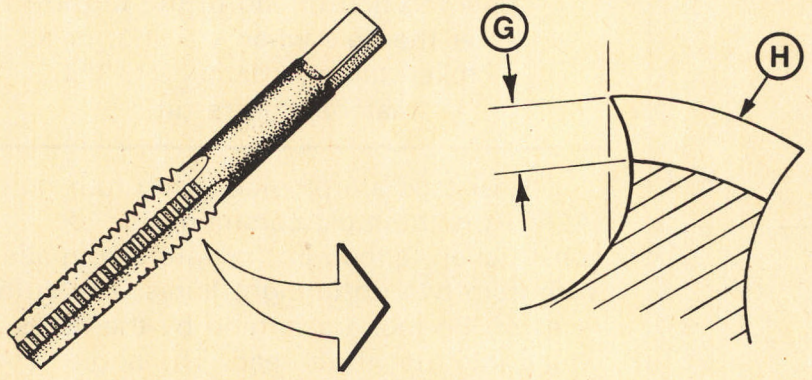
TAP CUTTING FACES



Radial Face: The *straight* cutting face (A) of a land (B) which, if continued forward, would pass through the centerline (C) of the tap.



Rake Face: The angle (F) of the cutting face of the land (E) in relation to a straight line (D) from the point of the cutting face to the center of the tap.



Hook Face: The *curved* undercut (G) of the cutting face of the land (H).

The three usual types of cutting faces provided for different materials are the radial-face, raked-face and hooked-face taps.

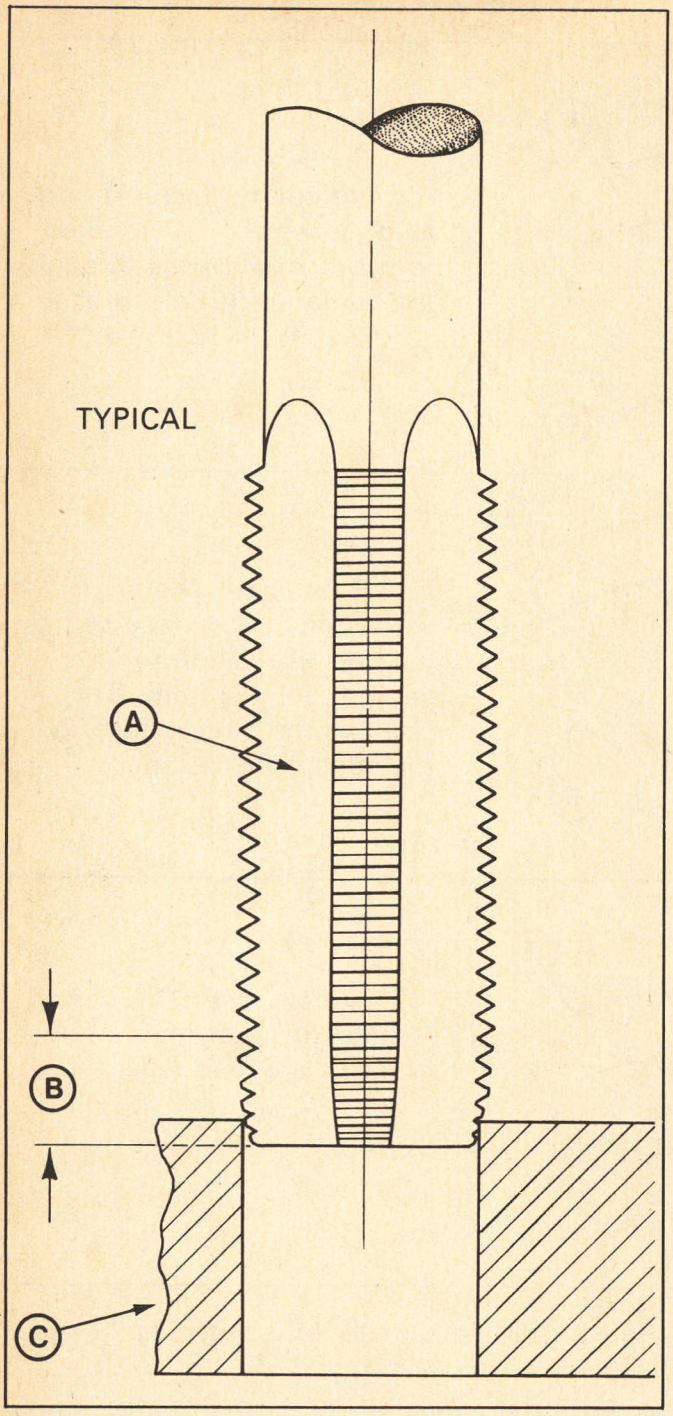
The radial face tap has its cutting face in line with the center of the tap, and the cutting angle thus formed is best suited for tapping cast iron.

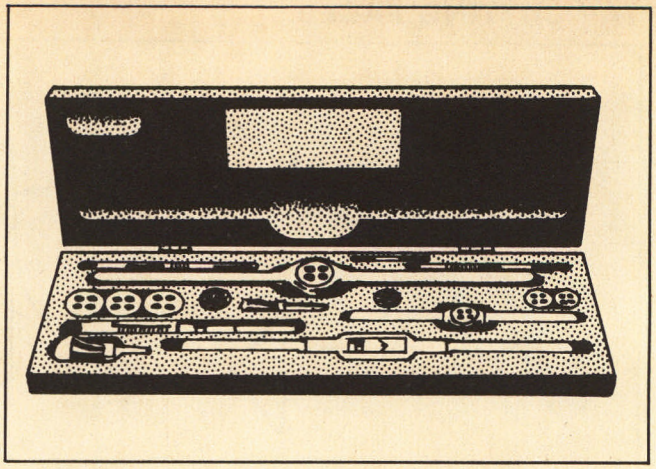
The cutting angle of the raked-face tap falls in back of the center to produce a rake angle of 10° to 15°. This design is used in tapping practically all steel and aluminum.

The hooked face tap has a still greater cutting angle of up to 20° and is used in tapping bronze, copper and nickel silver.

A standard design tap is also available for general-purpose work. The standard tap may be used with fairly good results on machinery steel, cold rolled steel, brass, cast iron, bronze and the most common plastics.

As we have pointed out, the construction of a tap consists of three main parts: the square, shank and body. The hand tap is operated by a tap handle (which will be discussed further on in this section) which is attached to the square. The shank connects the square to the body, and the body is provided with threads and flutes which cut new threads in the hole into which the tap is turned.



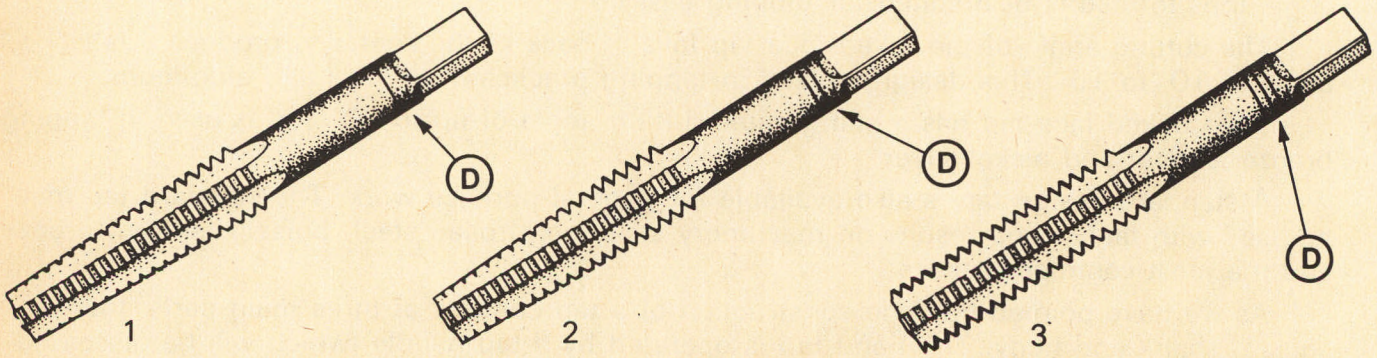


Note that the first five threads (B) of this tap are chamfered (tapered), while the remainder of the threads are straight. When the tap is screwed into the hole (C), these first threads do the rough part of the cutting while the straight threads do the finishing.

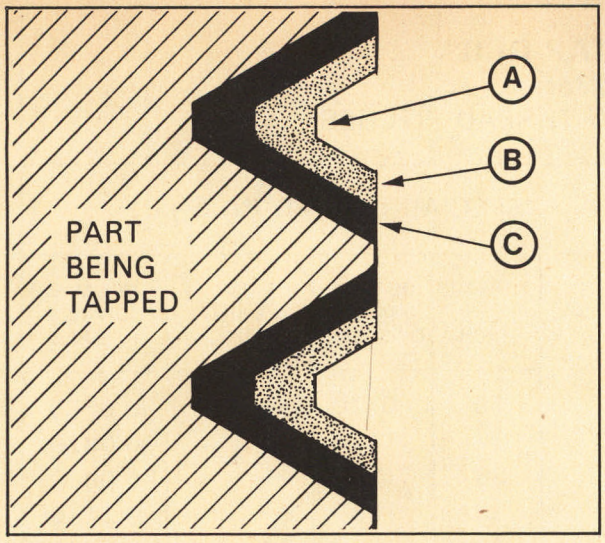
CAUTION

The small end of the chamfer must be of a size that will permit only the first thread of the tap to enter the hole when starting, or a broken tap and damage to the material can result.

Most taps are provided with four flutes (A). This is the most common type of construction, although they are also made with from two up to eight flutes. The cutting faces of the tool are formed by the flutes which interrupt the thread. The angle formed on the cutting face has much to do with the manner in which the tap operates, certain angles being most suitable for cutting specific materials.



Serial hand taps come in sets of three. They are very similar in appearance to the taper, plug and bottoming taps, but are classified as a No. 1, 2 or 3. The number of the tap is indicated by rings (D) cut in the shank.

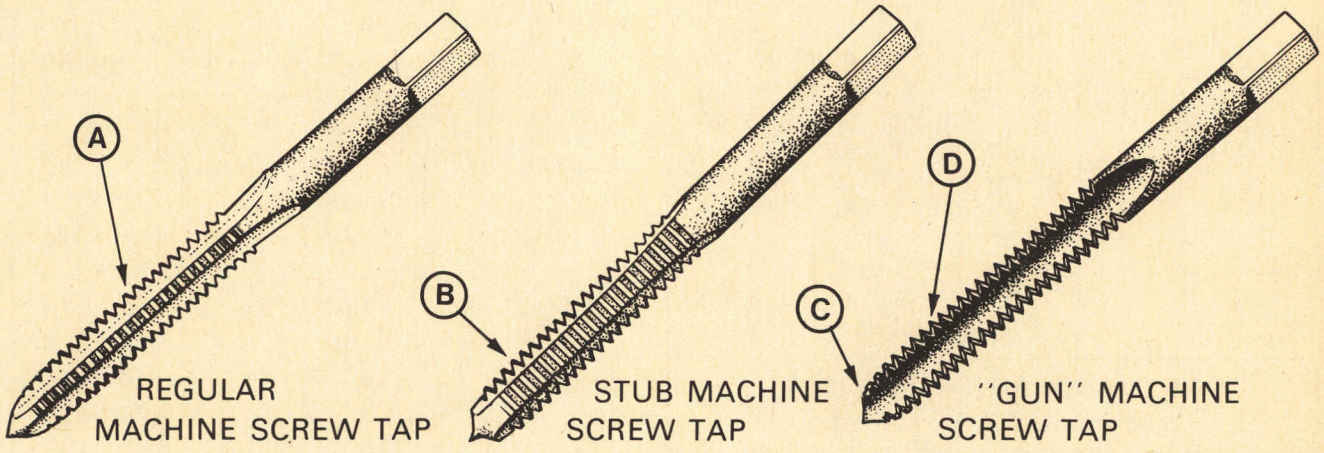


All thread diameters of the No. 1 serial tap (A) are smaller than the standard or basic size of the thread or the part being tapped. This tap is therefore used first in the hole and cuts only part of the metal away. The No. 2 tap (B) is slightly larger and removes more of the metal as it follows the No. 1 tap.

The No. 3 tap (C) is of the bottoming type, and the threads are full size so that it finishes the threads to size as it follows the No. 2 tap.

These taps are recommended for hand tapping deep, open or blind holes, especially in tough metals. They cut much easier and produce smoother threads than ordinary hand taps.

MACHINE SCREW TAPS



MACHINE SCREW TAP NUMBER	DECIMAL SIZE
No. 0	.060
No. 1	.073
No. 2	.086
No. 3	.099
No. 4	.112
No. 5	.125
No. 6	.138
No. 7	.151
No. 8	.164
No. 9	.177
No. 10	.190
No. 11	.203
No. 12	.216

Machine screw taps do not differ greatly from the hand taps so far described except as to size indicated by numbers on the shank of the tap. These numbers will range from 0 to 12 instead of the fractional sizes. Each number represents a certain decimal size, for which screws of corresponding diameter are made. The No. 0 size has a decimal equivalent of .060 and is the smallest in range. From this, all numbers are increased by .013-inch per size. Thus the decimal equivalent of the No. 1 size is .060 + .013 or .073, the No. 2 size is .073 + .013 or .086 and so on up to size 12 (see chart on this page).

The machine screw taps are available in taper, plug and bottoming types, although the plug is most often used. The *regular* machine screw tap (A) is used mostly to tap thin material and is weaker than taps (B) and (D). *Stub* taps (B) have tapered flutes (remember our previous discussion on flutes?) which gradually taper from the tip to the shank, providing a larger diameter flute and thus more strength. The "gun" tap (D) is made with an angular flute (C) on the end of the tool, which produces a shearing cut, requires less pressure to turn the tap and adds greater strength than taps (A) and (B).

MEASURING THE TAP DRILL

Recommended for
AMERICAN NATIONAL SCREW THREAD PITCHES

COARSE STANDARD THREAD (N. C.)
Formerly U.S. Standard Thread

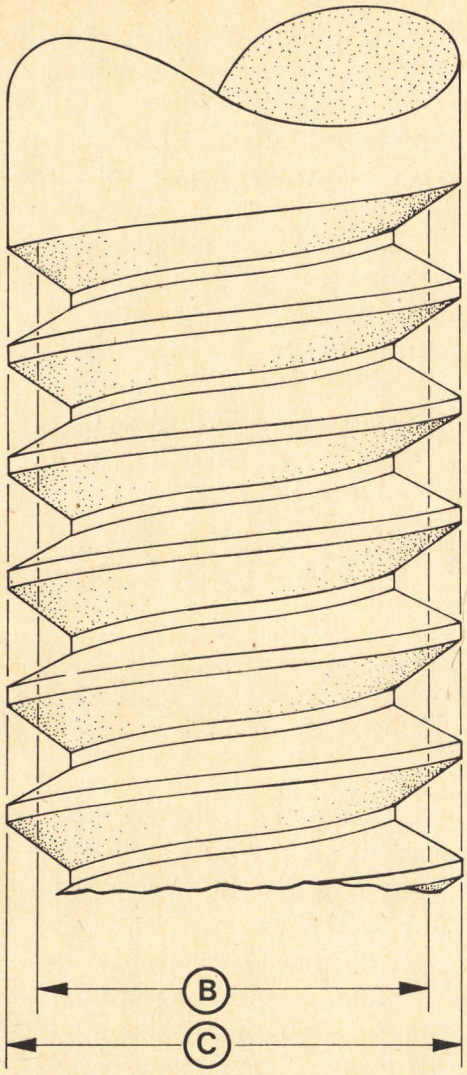
SIZES	THREADS PER INCH	OUTSIDE DIAMETER OF SCREW	TAP DRILL SIZES	DECIMAL EQUIVALENT OF DRILL
1	64	.073	53	0.0595
2	55	.086	50	0.0700
3	48	.099	47	0.0785
4	40	.112	43	0.0890
5	40	.125	38	0.1015
6 (A)	32	.138	36	0.1065
8	32	.164	29	0.1360
10	24	.190	25	0.1495
12	24	.216	16	0.1770
1/4	20	.250	7	0.2010
5/16	18	.3125	F	0.2570
3/8	16	.375	5/16	0.3125
7/16	14	.4375	U	0.3680
1/2	13	.500	27/64	0.4219
9/16	12	.5625	31/64	0.4843
5/8	11	.625	17/32	0.5312
3/4	10	.750	21/32	0.6562
7/8	9	.875	49/64	0.7656
1	8	1.000	7/8	0.875
1-1/8	7	1.125	63/64	0.9843
1-1/4	7	1.250	1-7/64	1.1093

FINE STANDARD THREAD (N. F.)
Formerly S.A.E. Thread

SIZES	THREADS PER INCH	OUTSIDE DIAMETER OF SCREW	TAP DRILL SIZES	DECIMAL EQUIVALENT OF DRILL
0	80	.060	3/64	0.0469
1	72	.073	53	0.0595
2	64	.086	50	0.0700
3	56	.099	45	0.0820
4	48	.112	42	0.0935
5	44	.125	37	0.1040
6	40	.138	33	0.1130
8	36	.164	29	0.1360
10	32	.190	21	0.1590
12	28	.216	14	0.1820
1/4	28	.250	3	0.2130
5/16	24	.3125	I	0.2720
3/8	24	.375	Q	0.3320
7/16	20	.4375	25/64	0.3906
1/2	20	.500	29/64	0.4531
9/16	18	.5625	0.5062	0.5062
5/8	18	.625	0.5687	0.5687
3/4	16	.750	11/16	0.6875
7/8	14	.875	0.8020	0.8020
1	14	1.000	0.9274	0.9274
1-1/8	12	1.125	1-3/64	1.0468
1-1/4	12	1.250	1-11/64	1.1718

SPECIAL THREAD (N. S.)

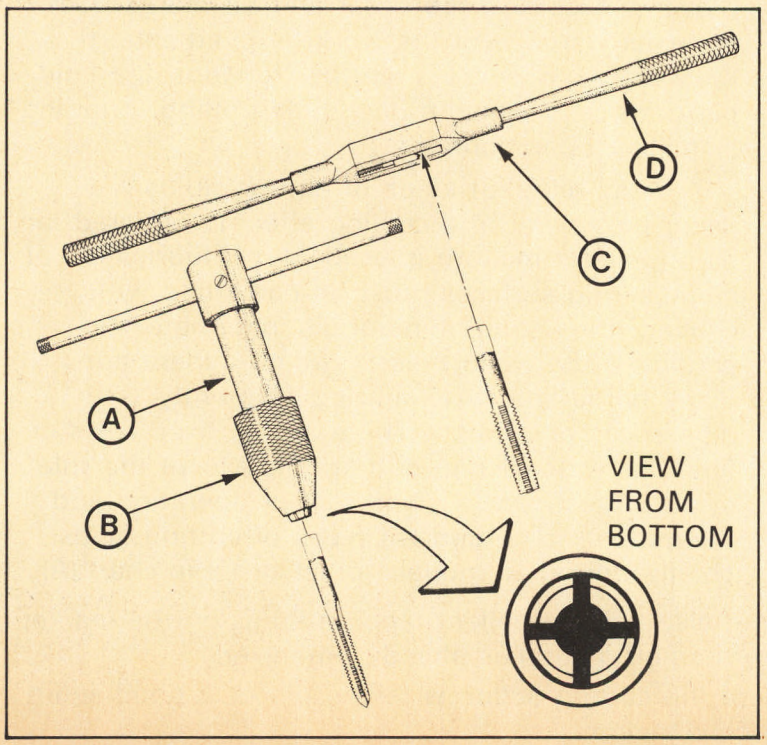
SIZES	THREADS PER INCH	OUTSIDE DAIMETER OF SCREW	TAP DRILL SIZES	DECIMAL EQUIVALENT OF DRILL
1	56	.0730	54	0.0550
4	32	.1120	45	0.0820
4	36	.1120	44	0.0860
6	36	.1380	34	0.1110
8	40	.1640	28	0.1405
10	30	.1900	22	0.1570
12	32	.2160	13	0.1850
14	20	.2420	10	0.1935
14	24	.2420	7	0.2010
1/16	64	.0625	3/64	0.0469
3/32	48	.0938	49	0.0730
1/8	40	.1250	38	0.1015
5/32	32	.1563	1/8	0.1250
5/32	36	.1563	30	0.1285
3/16	24	.1875	26	0.1470
3/16	32	.1875	22	0.1570
7/32	24	.2188	16	0.1770
7/32	32	.2188	12	0.1890
1/4	24	.250	4	0.2090
1/4	27	.250	3	0.2130
1/4	32	.250	7/32	0.2187
5/16	20	.3125	17/64	0.2656
5/16	27	.3125	J	0.2770
5/16	32	.3125	9/32	0.2812
3/8	20	.375	21/64	0.3281
3/8	27	.375	R	0.3390
7/16	24	.4375	X	0.3970
7/16	27	.4375	Y	0.4040
1/2	12	.500	27/64	0.4219
1/2	24	.500	29/64	0.4531
1/2	27	.500	15/32	0.4687
9/16	27	.5625	17/32	0.5312
5/8	12	.625	35/64	0.5469
5/8	27	.625	19/32	0.5937
11/16	11	.6875	19/32	0.5937
11/16	16	.6875	5/8	0.6250
3/4	12	.750	43/64	0.6719
3/4	27	.750	23/32	0.7187
7/8	12	.875	51/64	0.7969
7/8	18	.875	53/64	0.8281
7/8	27	.875	27/32	0.8437
1	12	1.000	59/64	0.9219
1	27	1.000	31/32	0.9687



A drill used to produce a hole of diameter (B) is called a ''tap drill'' because it performs the operation prior to tapping. It is not usually necessary to calculate the size of the tap drill to use with a certain tap, since this information is available to you in numerous tables (A) and in most cases is indicated on the shank of the tap itself. But if you do not have a table available and the tap you are using has a worn or faded shank, the following information will allow you to determine the proper size drill to use.

The size of tap drill suitable for producing a hole in which National Coarse (NC), National Fine (NF) or Special thread (NS) (machine screw thread) is to be cut may be obtained by subtracting the pitch diameter (B) from the major diameter (C) of the screw or tap and selecting a drill to the nearest size under this value. Example: If you had a 1/2-inch screw or tap with 13 threads per inch (NC), it would require a drill of .500 -inch or major diameter (C). One thirteenth (one of the threads or pitch diameter [B]) has the decimal equivalent of .077 (or 13 divided into 1.000); therefore, .500 minus .077 equals .423. Looking in your drill holder, you will see that the next size under .423 would be a .421.

There are many kinds of taps on the market and each is designed to perform a specific function. We will talk about some of these other taps and their specific uses further on in the text. The taps covered in this section will aid the automotive mechanic (or any mechanic) to fully understand taps and their operation.

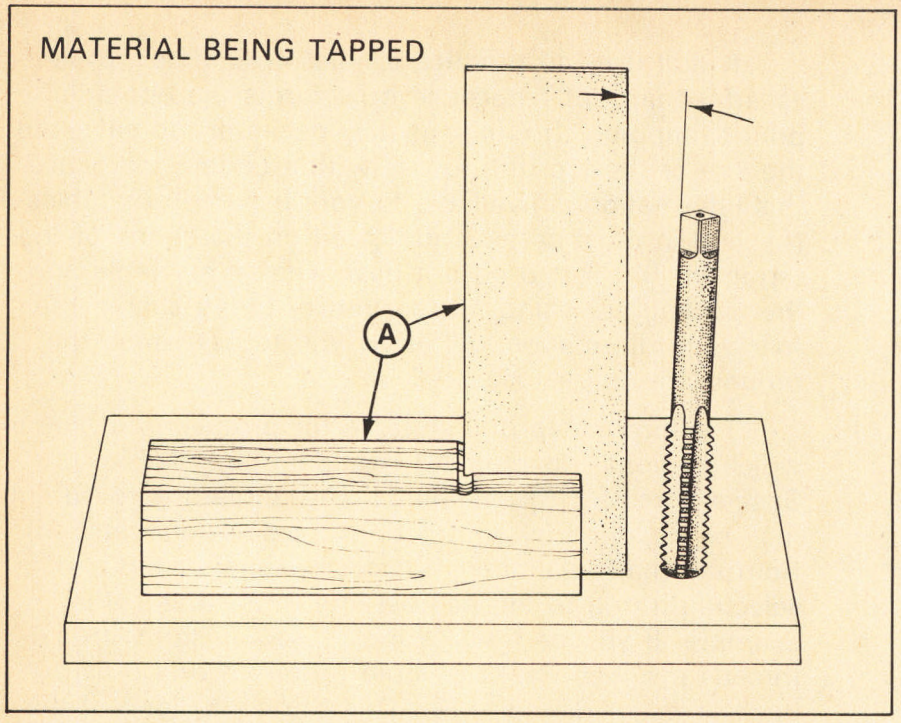


TAP HANDLES

Two types of tap handles are shown here. The type to be used depends on the diameter of the tap. The ''T'' tap handle (A) should be used for all machine screw taps as well as fractional sizes up to the maximum capacity of the chuck (B). A more sensitive ''feel'' is obtained with this wrench, so that any twisting action of the tap will be noticed and breakage will not be so apt to occur. The tap handle (C) is used for larger taps which require greater turning power.

The tap is inserted into the tap handle by rotating the chuck (B) or handle (D) counterclockwise wide enough to accept the tap. Insert the square of the tap only and tighten the chuck (B) or handle (D).

TAPS AND DIES



USING THE TAP

When tapping by hand, the chief requirement is to make sure the tap enters the hole straight and remains in line with the hole during the entire operation. The tap is aligned in the hole by sight. After two or three turns, the tap is again sighted or checked for alignment with a small machinist's square (A). The picture here shows how the machinist's square detects a misaligned tap in a hole.

(A)

MATERIAL	LUBRICANT
Mild Steel	Mixture of 75% Engine Oil and 25% White Lead
High Carbon and Alloy Steel	30% Lard Oil with 90% Mineral Oil
Hard Steel	Turpentine
Brass	20% Lard Oil with 80% Mineral Oil
Copper	Lard Oil
Aluminum	Drycleaning Solvent Lard Oil
Monel Metal	Lard Oil and White Lead
Cast Iron	Dry

TAP LUBRICANTS

A tap or die should *never* be operated dry except in the case of cast iron, so here is a word on the use of lubricants, a very important factor in the use of taps and dies.

The function of a cutting fluid varies somewhat for different metal-cutting operations. In general, the fluid serves to prevent excessive heating of the tool and material (especially when removing metal rapidly in taking roughing cuts), prevents excessive tool wear and, in many cases, prevents warpage of the work by overheating. Washing away chips is another function the fluid performs, especially in deep-hole drilling, grinding or milling operations.

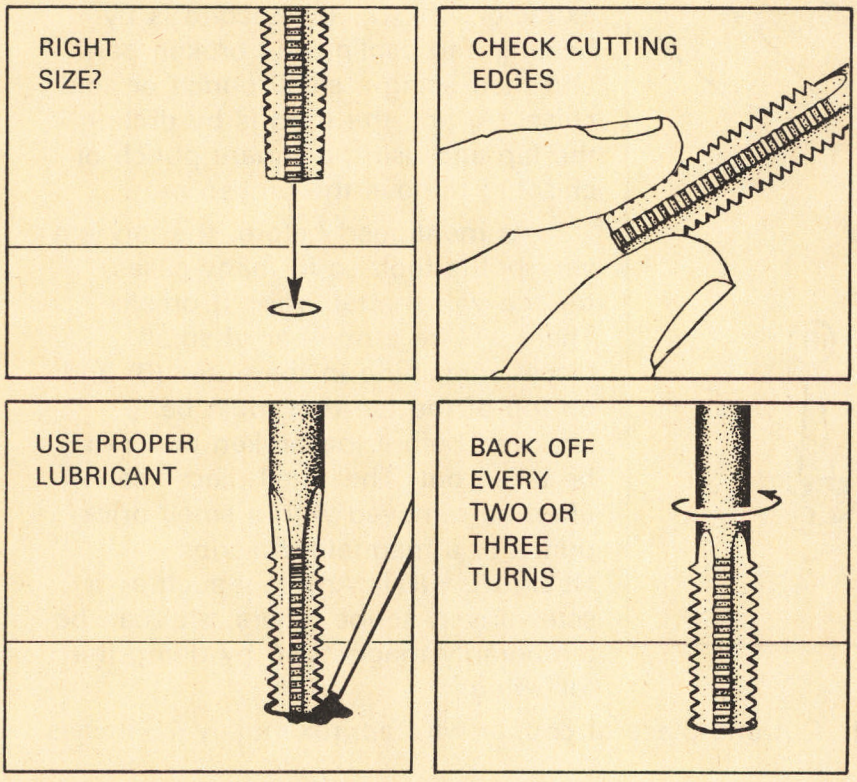
Many different kinds of cutting fluids are used. In general, if a cooling effect is required, an oil and water mixture is used. But if lubrication of chip-bearing surfaces must be combined with cooling, then some mineral oil combination is employed. Between these extremes, there are many borderline cases and consequently differences of opinion. There are no fixed rules or formulas for selecting cutting oils except the rule of actual test with a given tool or operation and the material. The general types of cutting fluids chiefly utilized in modern practice are in chart (A).

For small hand tapping jobs, there are also some excellent tapping fluids on the market (your local automotive store) which come in small quantities already pre-mixed.

Cutting fluids should be applied where the cutting action is taking place. A good squirt of cutting fluid will aid in washing away chip buildup.

SOME HAND TAPPING PROBLEMS

If certain points are not observed, trouble may be experienced in tapping which may result in tap breakage. The following points should be observed if trouble is suspected:

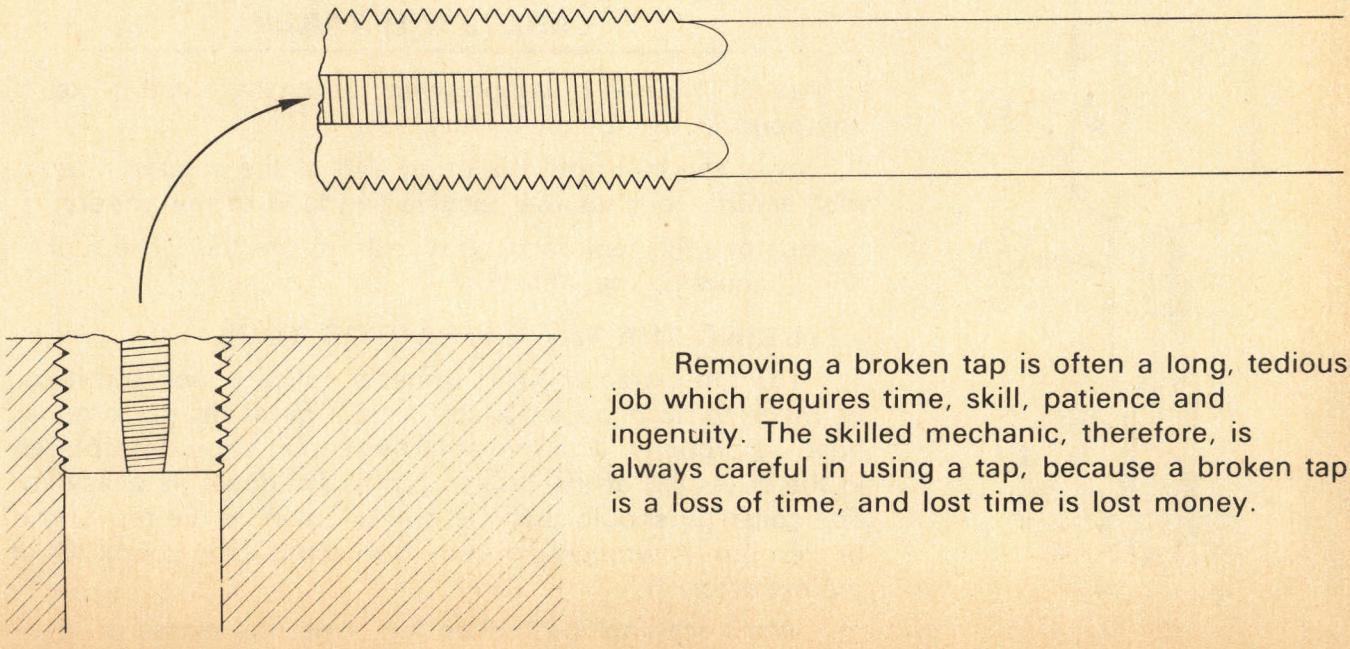


- Be sure that the tap is the correct size for the hole. If too much metal is removed at one time, the strain will be so great that the tap will break.
- Check the cutting edges of the tap to be sure they are not dull or damaged.
- Be sure you are using the right kind of lubricant and enough of it.
- Be sure to back off the tap a half turn counterclockwise after every two or three turns. This breaks the chips, allows them to drop down the flutes with the lubricant and prevents the chips from plugging up and tearing the new threads.

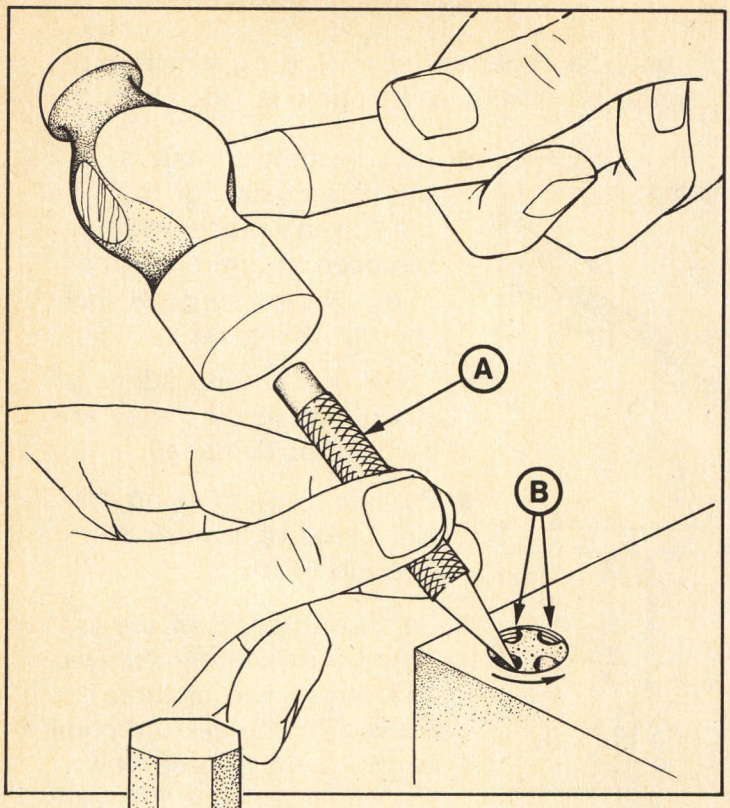
If the tap stops and begins to twist or to spring, do not force it beyond this point. Back it out carefully and check the points mentioned above. If the twisting did not result from the above points, it is possible that the material is very hard and serial taps should be used.

Be careful not to run the tap into the bottom of the hole. If the tap does bottom out, do not continue to apply pressure. Also, be sure that the bottom of the hole does not fill up with chips and in so doing, jam the tap. Periodically remove the tap and clean the hole out.

HOW TO REMOVE BROKEN TAPS



Removing a broken tap is often a long, tedious job which requires time, skill, patience and ingenuity. The skilled mechanic, therefore, is always careful in using a tap, because a broken tap is a loss of time, and lost time is lost money.



In the event of a tap breaking off in a hole, one of three methods may be used in attempting to remove it. The first is by means of a tap extractor tool (D), the second is by heating and cooling the broken part and then using a small punch or cold chisel (A) and the third is by drilling the tap and using a square punch or chisel to remove the broken part.

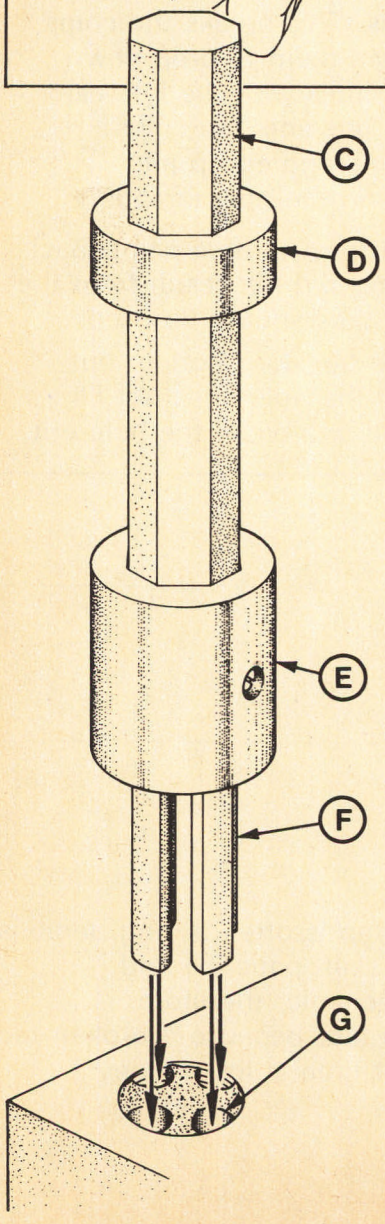
As mentioned before, the tap is a very brittle tool, so in many cases, the tap will shatter when it breaks. There will be a number of small pieces remaining in the flutes (B) and on top of the tap that must be removed before the broken end can be taken out. The small pieces can often be removed with a small prick punch or a magnetized scribe.

HELPFUL HINT: Any tool such as a screwdriver, scribe, pliers, etc. can be temporarily magnetized by doing the following:

1. Cut one piece of copper wire approximately 18 inches long.
2. Starting in the center of the wire, wrap approximately 12 loops, spaced approximately ½-inch apart, around the tool handle or shaft.

WARNING
THE COPPER WIRE WILL BECOME EXTREMELY HOT, SO BE SURE TO WEAR GLOVES OR HOLD THE TOOL'S PLASTIC HANDLE WHEN MAGNETIZING A TOOL. BURNS TO THE HANDS CAN RESULT IF CARE IS NOT TAKEN.

3. Attach one end of copper wire to negative lead (–) of any good 6- or 12-volt battery.
4. Lower the tool until the other end of the copper wire *momentarily* touches the positive (+) lead of the battery.
5. Remove the tool and the wire from the tool. The tool should now be magnetized.

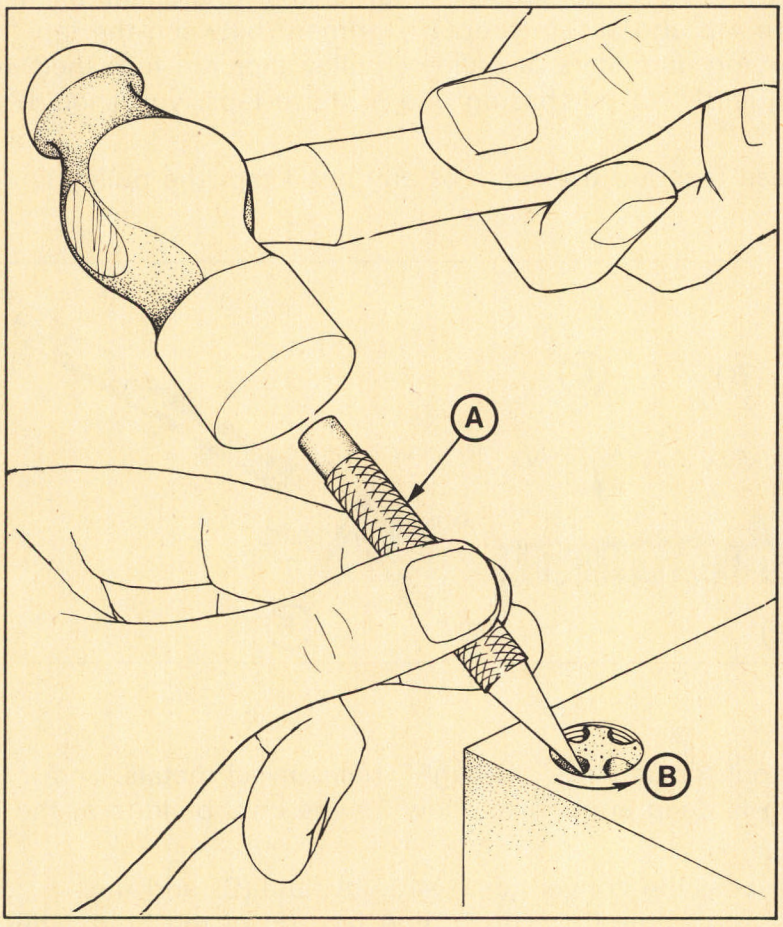


USING THE TAP EXTRACTOR TOOL

The tap extractor (D) is rather a delicate tool, but it can be made to do good work and save a great deal of time if handled properly. The movable fingers (F) should be placed in the flutes (G) of the broken tap as far down as possible. The collar (E) should then be pulled down to the top of the broken tap. A wrench can now be used on the shank (C) of the extractor.

When starting the broken tap, twist the extractor

slightly back and forth a few times to loosen the tap in the hole (this may break loose some built-up chips between the tap teeth and the metal being cut). Lightly tapping the end of a shank with a small mallet will sometimes jar the broken tap loose and allow it to start easier. A small punch and hammer can also be used to break the broken tap loose before using the extractor. Always use *plenty* of liquid wrench or anti-seize liquid when attempting to remove a broken tap.



USING THE HAMMER AND PUNCH

The following method works extremely well but must be used with extreme care or damage to the part in which the tap has been broken off could occur.

The broken tap should be heated with a butane torch or a welding torch and then chilled immediately with ice water, CO^2 fire extinguisher bottle or dry ice. Concentrate the cold solution on the broken tap only. Immediately after applying the cold solution to the broken tap, attempt to drive the tap in a counterclockwise direction (B). It may take two or three heatings and chillings before the broken tap begins to move, but it will.

What you have essentially done here is two things. First, by heating and chilling, you have changed the internal structure of the tap metal, thus weakening it. Secondly, you have caused the tap metal to contract or shrink just enough to be moved.

USING THE DRILL

If the two methods previously mentioned do not prove effective, the tap must be drilled out. This is a very delicate operation. The metal of the broken tap should be heated until very hot (red in color) and then rapidly chilled as described in method two (using the hammer and punch).

The drill used should be considerably smaller than the body of the tap. Never use a ''tap drill'' to drill the broken tap. This will enlarge the hole and damage the threads in the part being tapped.

Using a center punch and hammer, sharply strike the center of the broken tap. This will give the point of your drill a starting place. After the hole has been drilled all the way through the broken tap, take a square punch or small cold chisel and drive it into the hole (it won't go far—just enough to grip the broken tap). Using plenty of anti-seize liquid and a wrench on the shank end of the punch or chisel, remove the broken tap.

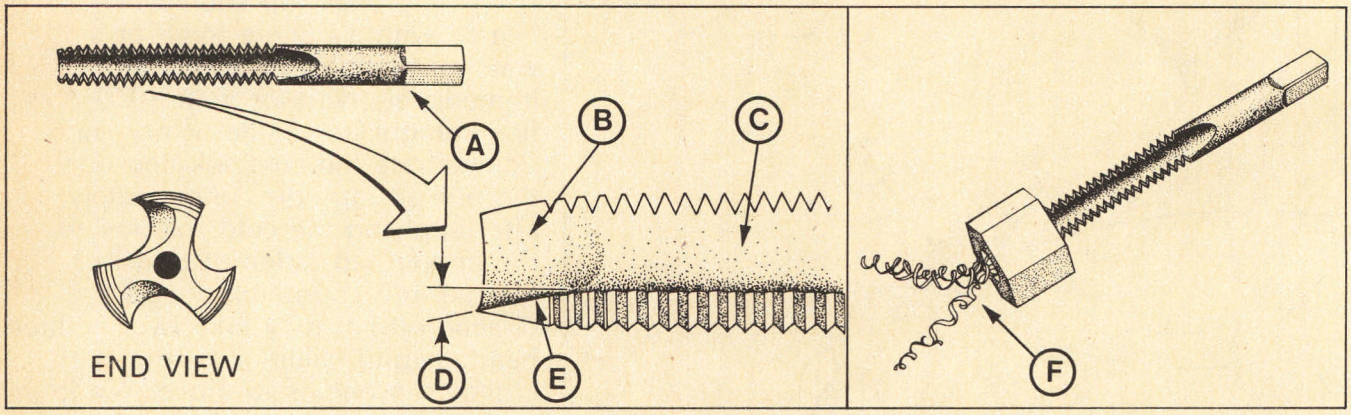
SPECIAL TAPS

In addition to the hand taps described previously, there are numerous other types available. These additional taps are designed for specific tapping jobs and are named according to the jobs they perform. The general design and cutting principles of these taps are similar to those already described.

PULLEY TAPS

As the name indicates, the pulley tap (A) is used for threading holes in pulleys. In the hubs of these pulleys are oil cups and set-screw holes, the majority of which cannot be reached with the ordinary hand tap. When tapping holes in pulley hubs, the tap is inserted through holes in the rims of the pulleys (the holes being slightly larger than the shank of the tap). These holes serve as guides for the tap and assure proper alignment between the tap and the hole in the hub. Due to the varying diameters of pulleys, pulley taps are furnished in several different overall lengths. Consequently, in purchasing one of these taps, you should specify the overall length needed.

The basic thread dimensions of these taps are the same as any hand tap; the pulley tap simply has a longer shank.



"GUN" TAPS

The "gun" tap (A) is an excellent tool for tapping "through" holes in all metals, and it is equally good for blind holes if drilling is deep enough to allow for the chip buildup at the bottom of the hole.

The flutes are divided into two sections, the conventional straight flute (C) and the angular section at the point called the "gun" flute (B). The cutting face (E) of the "gun" flute is ground to an angle (D) relative to the straight flute of the tap. This causes the tap to cut with a shearing action. The angle (D) deflects the chips so that they curl out and ahead of the tap (F). Consequently, the chips do not collect and break up in the flutes.

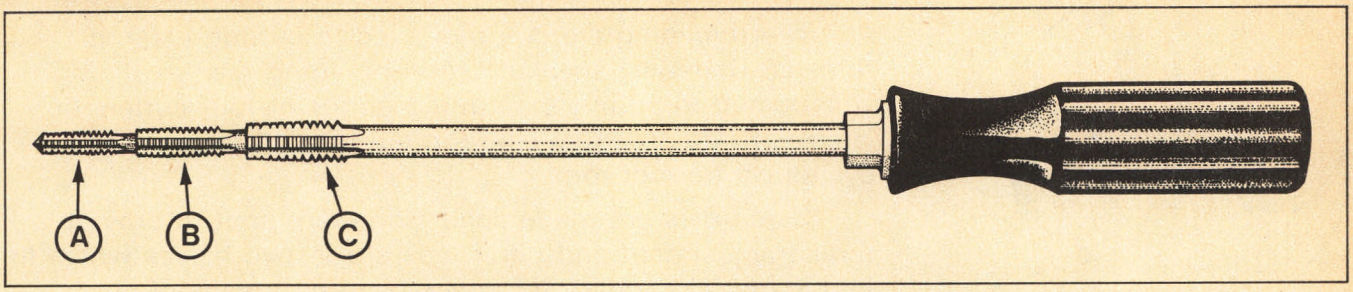
This feature of ejecting chips is very desirable when tapping "stringy" metals such as aluminum and brass, for it eliminates the possibility of loading (excessive buildup) in the flutes, a frequent cause of tap breakage. Furthermore, when backing out or reversing the tap, the danger of damage to the threads in the tapped part by chips in the flutes is eliminated.

The "gun" tap has fewer flutes than most other taps and it is made very shallow, thus providing greater tap strength. Due to this type of design, less power is required to drive the "gun" tap.

PILOT TAPS

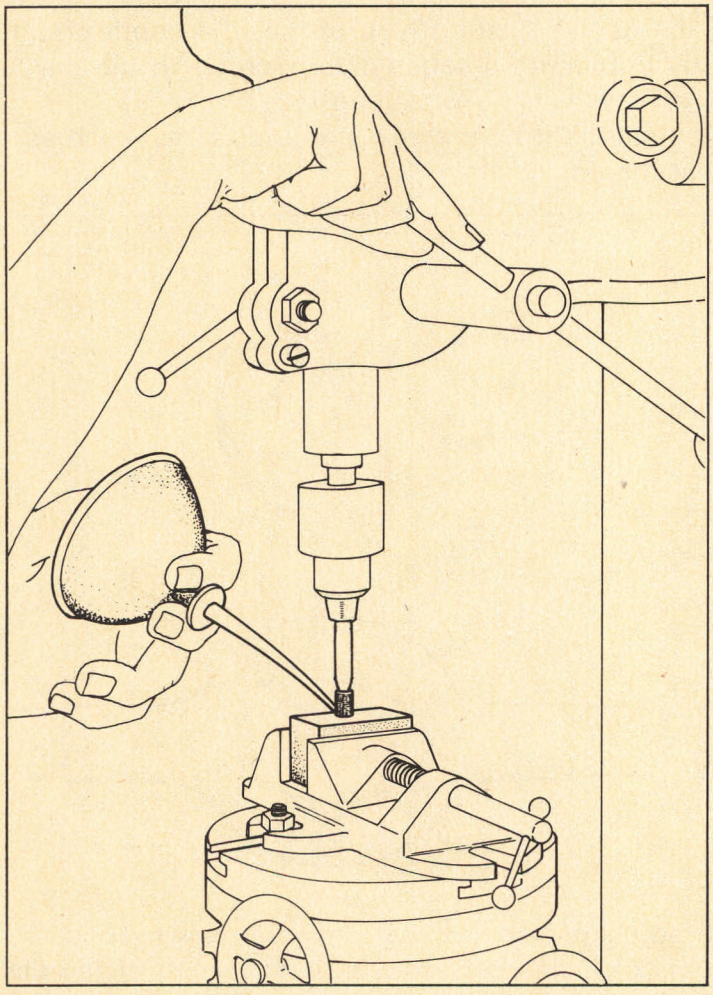
Quite frequently, taps of special design are provided with pilots (A) ahead of the threaded section for the purpose of obtaining alignment. Such a tap is the pilot tap (B). Controlling the size of drilled holes when using such taps is most important, because holes looser than a free fit for the pilot defeat its purpose, while tight holes add an unnecessary load to the tap.

SCREWDRIVER TYPE TAP



Another handy tap on the market is the ''three taps in one'' with a screwdriver handle. This tool is great for tapping ''through'' holes in thin material. The tap sizes of the tool shown range from 6 – 32 (A), 8 – 32 (B) and 10 – 32 (C), all National Fine (NF). This tool also comes in the National Coarse (NC) threads in various sizes.

If the hole to be tapped is for a 10 – 32 screw, naturally the other two taps (A) and (B) would go through the hole to utilize the 10 – 32 portion (C) of the tap. This is a very handy tool for small jobs.



USING THE DRILL PRESS

If the need to tap a part in a drill press arises, the following information will be helpful:

WARNING
ALWAYS WEAR YOUR SAFETY GLASSES WHEN OPERATING *ANY* POWER MACHINE.

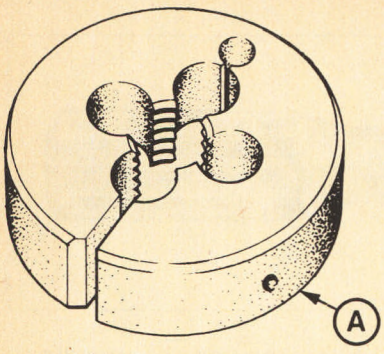
When tapping in a drill press, several points must be watched carefully. The setup must be carefully made to be sure the tap is tight in the drill press chuck and the part being tapped is tight in the holder. There are many different kinds of holders and clamps used, depending on the particular part being drilled or tapped. Choose the correct one that best holds your part securely.

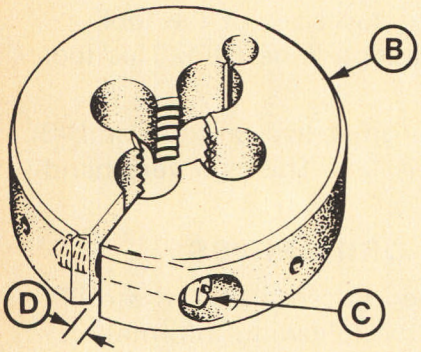
The hole in the work must be correctly aligned with the tap, and the work must be held rigidly so it will not move while the tap is being driven into the hole or withdrawn from it. Be sure tap is sharp and running true (straight).

When the setup is first made, use a slow speed on the drill press and gradually increase it to the maximum speed allowable for the particular material being tapped. A flood of cutting lubricant should be applied to the hole in which the tap is working unless the material is cast iron, in which case a jet of air may be used to cool the tap.

It is a good plan to reverse the tap in the work occasionally to break the chips when tapping deep holes. (This is not necessary when using a ''gun'' tap.) When a soft material such as brass or copper is being tapped, the tap should be entirely removed from the hole several times to clear it of chips.

TAPS AND DIES





HAND-OPERATED DIES

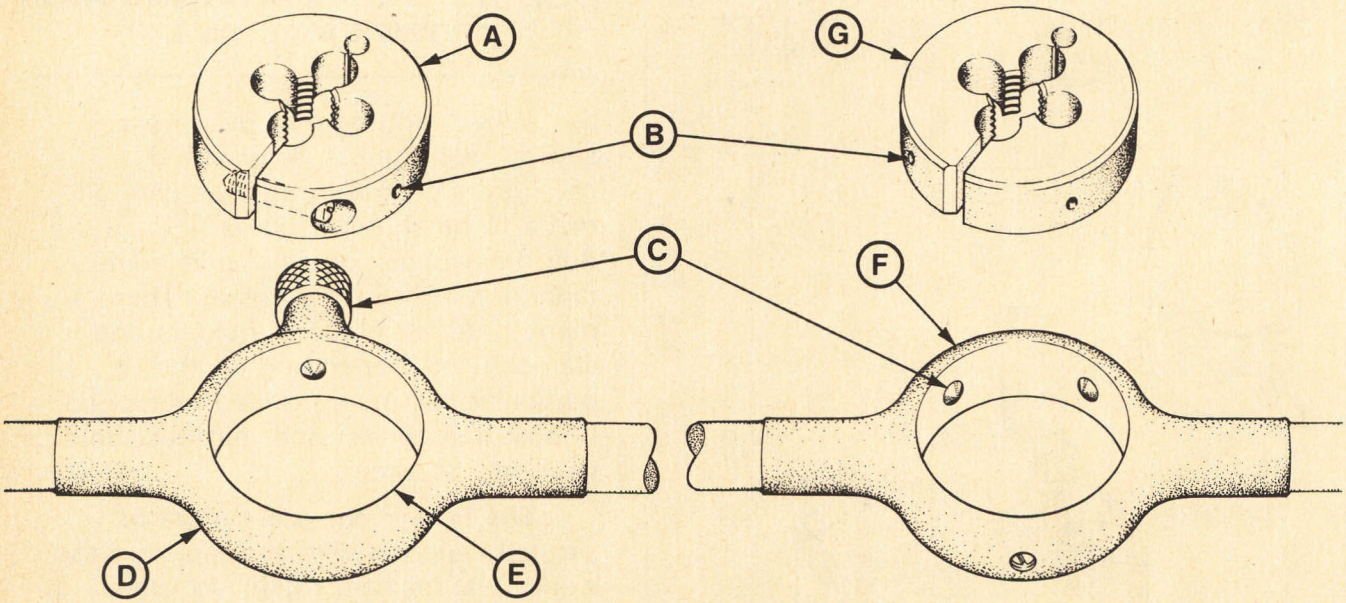
The threading die is a tool used in cutting external threads. Generally speaking, the threading die is constructed to permit the cutting edges of four cutters or chasers to do an equal share in cutting a thread on a cylindrical (round) rod.

Some dies are made solid, some are split to provide a thread adjustment and other dies are in two halves which fit into a special handle. Solid dies have no means of adjustment to control the fit of the thread they cut and for this reason are seldom used. The most popular dies for hand use today are the adjustable round split type.

The two most used forms of adjustable round split dies are the open-adjusting type (A) and the screw-adjusting type (B). Tightening the adjusting screw (C) of the screw-adjusting type of die forces the split opening (D) of this die wider apart, causing a thread of lesser depth to be cut. When using the open-adjusting type of die, the depth of cut is regulated by tightening a series of set screws in the die handle. This process will be explained later.

Dies are available for cutting threads for all standard bolt, screw and pipe sizes, such as NC, NF, machine screw, pipe and other special threads.

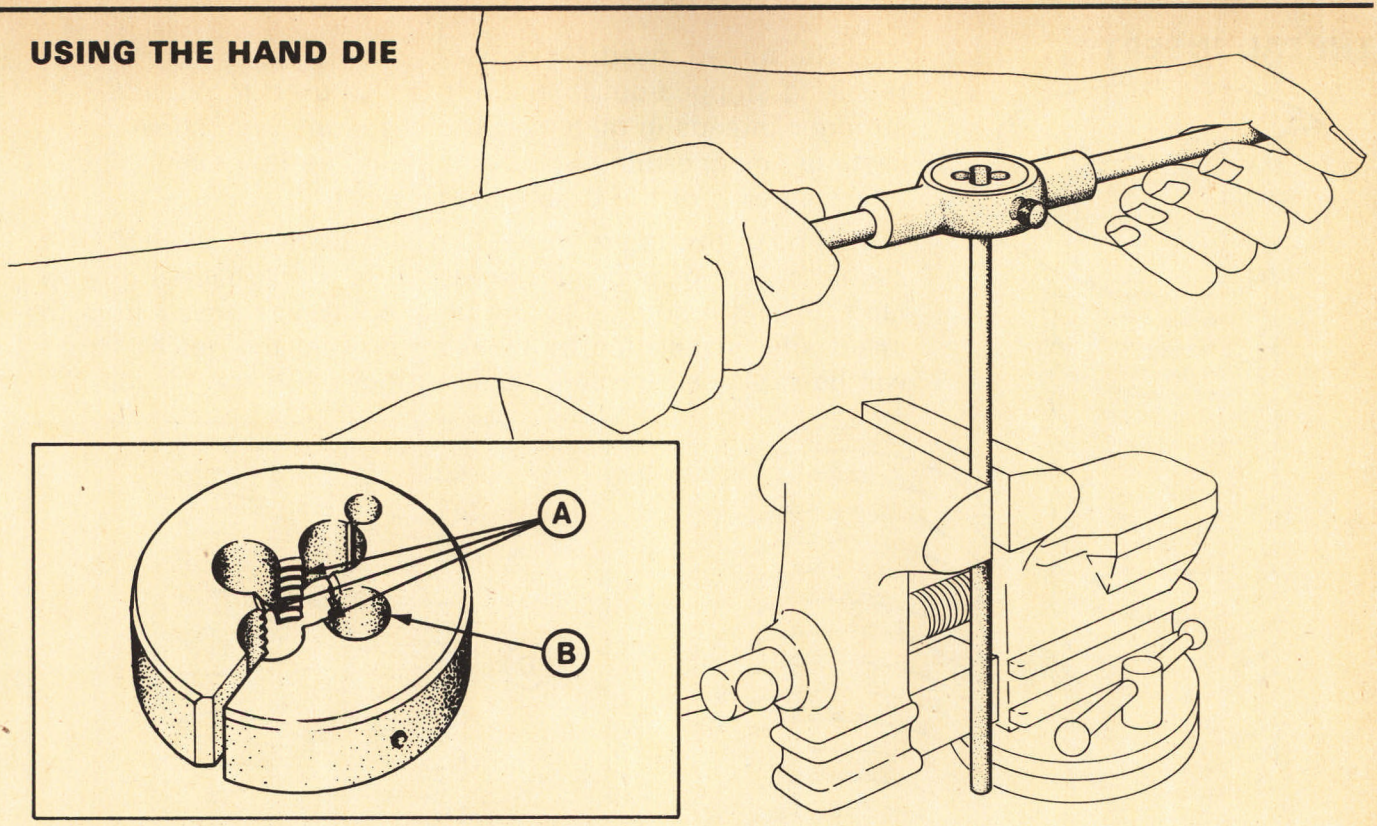
DIE HANDLES



The most common die handles used with adjustable round split dies are shown above. The die is placed in the opening (E) (with recess [B] facing set screw[s] with recess) of the die handle. The die is locked securely in position by one or more set screws (C). The single set-screw type of handle (D) is designed to accommodate round dies of the screw-adjusting type (A). The set screw in the die handle is located in such a position that it enters a recess (B) provided for it in the side of the die. The die will fit in the handle closely, thus finger pressure on the set screw is sufficient to secure it firmly.

The three-screw kind of handle (F) is designed to hold round, adjustable dies of any construction, although they are specifically manufactured for holding dies of the open-adjusting type (G). Tightening the three set screws (C) secures the die in place and also exerts sufficient pressure at the right points to close the die teeth for a deeper cut.

USING THE HAND DIE



The correct method of holding and operating thread-cutting dies is as follows:

It is important that the part being threaded be supported securely, so it will not move during the threading process. Before using adjustable dies, always check first to see that the die is properly set. Never assume that the die is set correctly for the thread it is required to cut. To be safe, back off the adjusting screw(s) and make a trial cut on the rod to be threaded. Then test the fit of the thread on a nut or other internal thread into which it is to be screwed.

If the fit is too tight, turn the adjusting screw(s) on the die head (or die handle) so a deeper cut will be taken with the next trial cut. After running the die over the threads again, make another trial fit and repeat this procedure until the threads have been cut to the correct depth. *Remember,* when too much metal has been carelessly removed by a single cut of too great a depth, it is too late to correct the error. The damage is done.

CAUTION

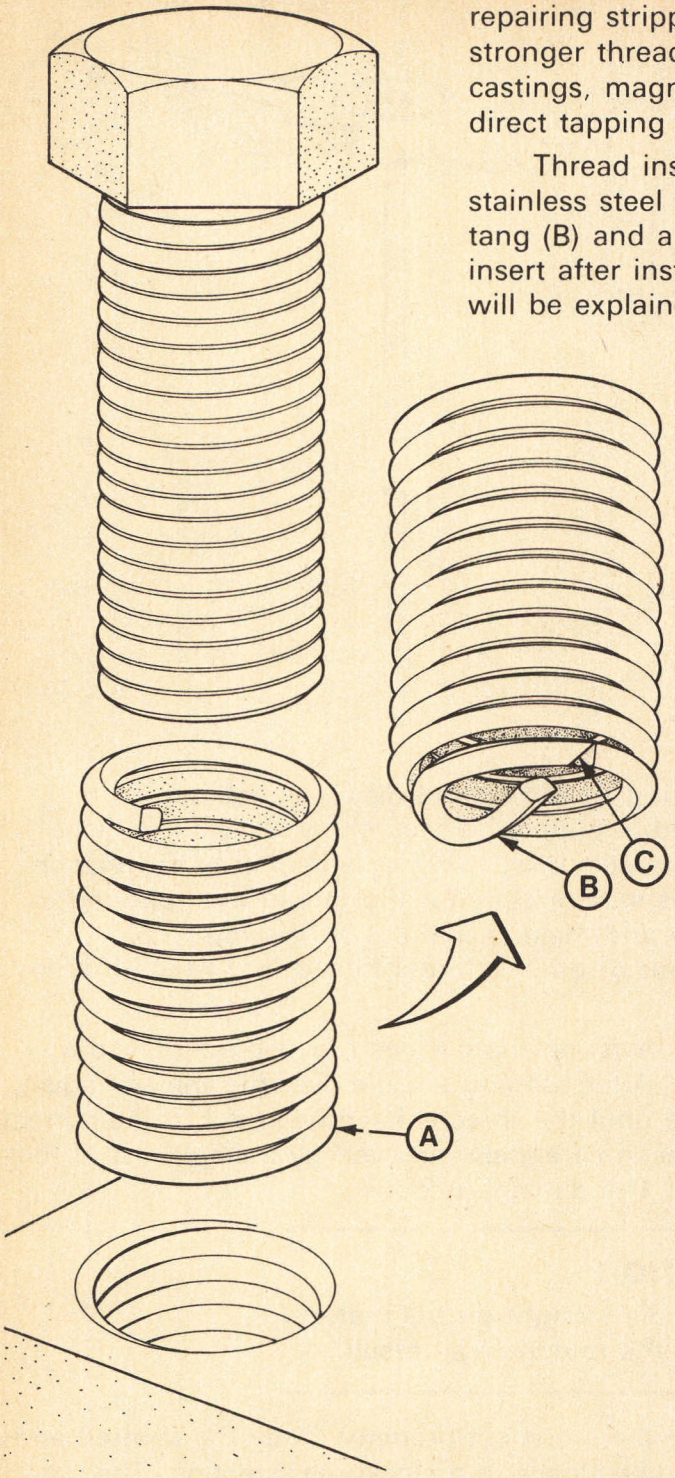
Be sure to keep the die handle straight on the material being cut or damage to the material can result.

When cutting a thread on a rod, make sure the die is set properly. Place the tapered ends of the die (A) on the rod. Then turn the die handle slowly in a clockwise direction. The die should be backed off after every two or three turns to break the chips, and lubricant should be applied freely to the dies in the same manner as for taps.

In cutting, the die operates just like the tap. The chips that are formed in the cutting are eliminated with the lubricant down the flutes (B) of the die.

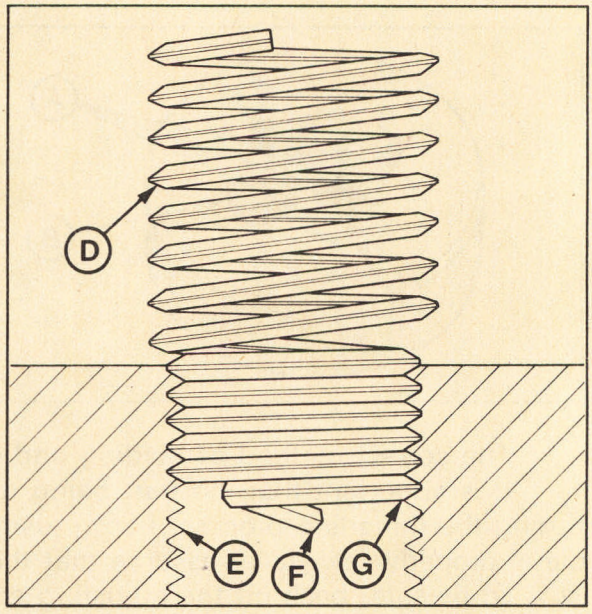
HELPFUL HINT: When it is necessary to cut the full depth of thread up to the very end of a rod or bolt, first cut the thread as far down as possible in the usual manner. Then back the die completely off, reversing it in the handle so the tapered end of the die points away from the rod or bolt. Rethread it on the rod or bolt and turn it all the way down as far as possible. Never attempt to use the die in this manner without first having started the thread in the conventional way described above; this would be the same as using a bottoming tap in a hole without preceding it with a taper or plug tap.

THREAD INSERTS



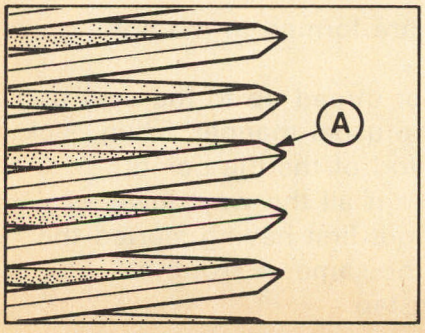
The thread insert (A) provides a convenient means of repairing stripped-out threads. It is also used to provide stronger threads in materials such as aluminum, some soft castings, magnesium, wood, etc. than can be obtained by direct tapping of the base material itself.

Thread inserts are formed coils of diamond-shaped stainless steel or phosphor bronze wire which have a driving tang (B) and a notch (C). The tang is easily removed from the insert after installation by breaking it off at the notch. This will be explained in more detail further on in the section.



Before installation, the thread insert (D) is slightly larger in diameter than the hole (E) in which it is going. In the assembly operation, the torque applied to the tang (F) reduces the diameter of the leading coil (G) and permits it to enter the tapped thread. When the torque action stops, the coils expand into the tapped threads with a spring-like action, anchoring the insert in place. Another fine point of the thread insert is that it automatically adjusts itself to any expansion or contraction (caused by temperature changes) of the material in which the insert has been placed.

SELF-TAPPING THREAD INSERTS

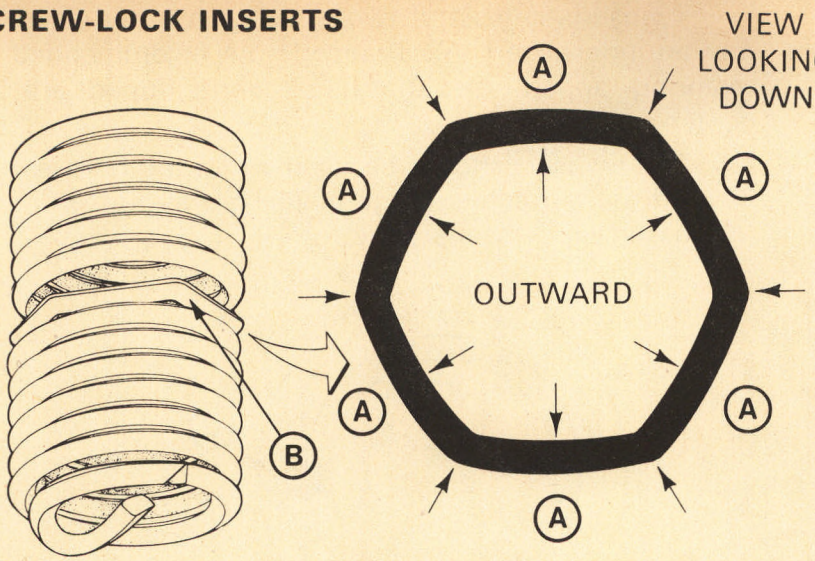


Self-tapping thread inserts are essentially hard bushings (linings) with internal *and* external threads. The external threads (A) have cutting edges that provide the self-tapping feature.

These inserts may be used to repair damaged threads in soft metals such as magnesium, aluminum and cast iron and in plastics.

Self-tapping inserts are made of case-hardened Carbon Steel, stainless steel and brass.

SCREW-LOCK INSERTS

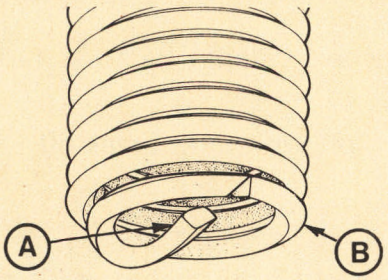


The standard (previously shown at the beginning of this section) and screw-lock inserts are identical except for a number of flats (A) on the middle coil or grip of the insert. These inserts are dyed red for easy identification and are used to lock screws, bolts and studs and prevent them from loosening under impact and vibration. They eliminate the need to lock-wire or use lock nuts to secure a fastener.

The locking action of the insert is achieved when the bolt enters this grip coil (B) and the flats (A) flex outward, creating pressure on the bolt between the bolt threads.

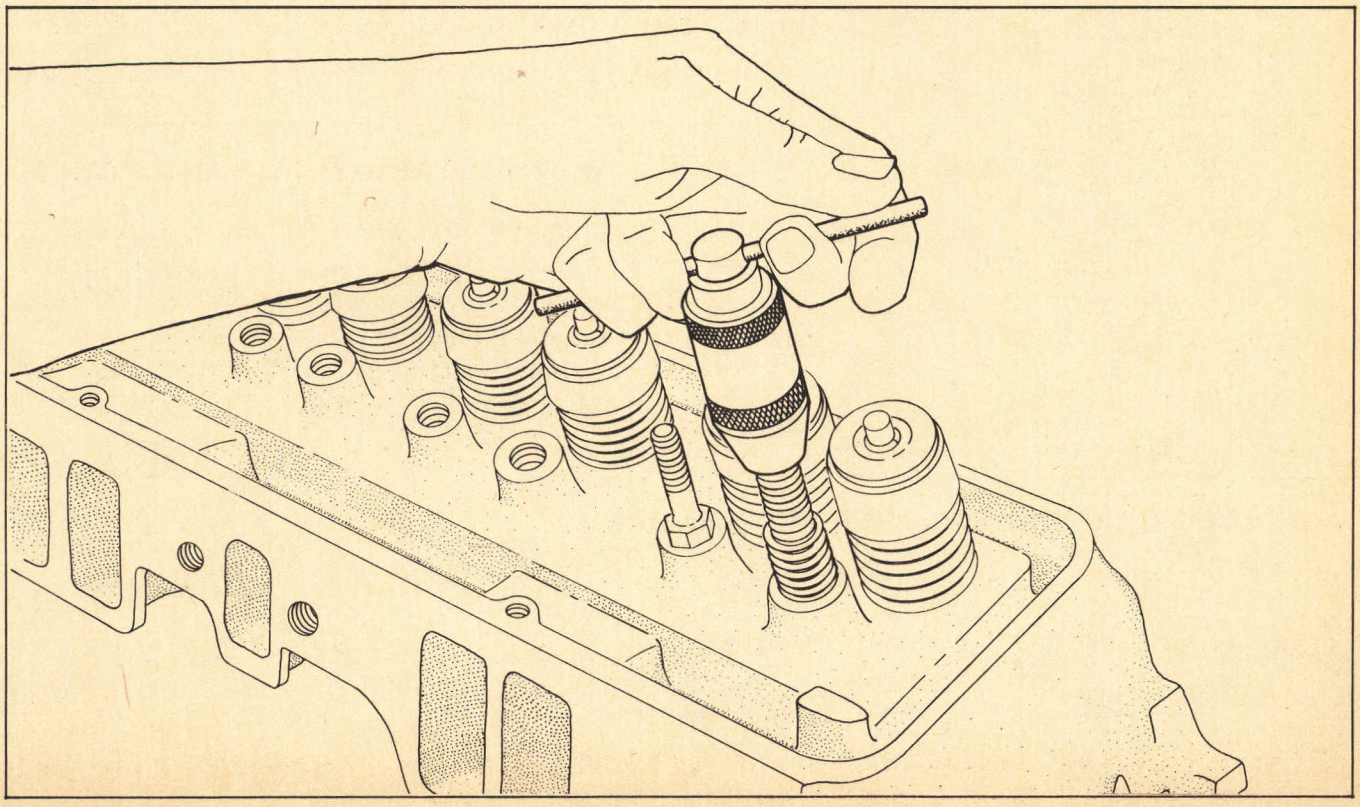
Screw-lock inserts permit repeated assembly and disassembly yet will not relax their grip on the screw even on tough metals such as cast iron, alloy steel, titanium, etc.

OVERSIZE INSERTS

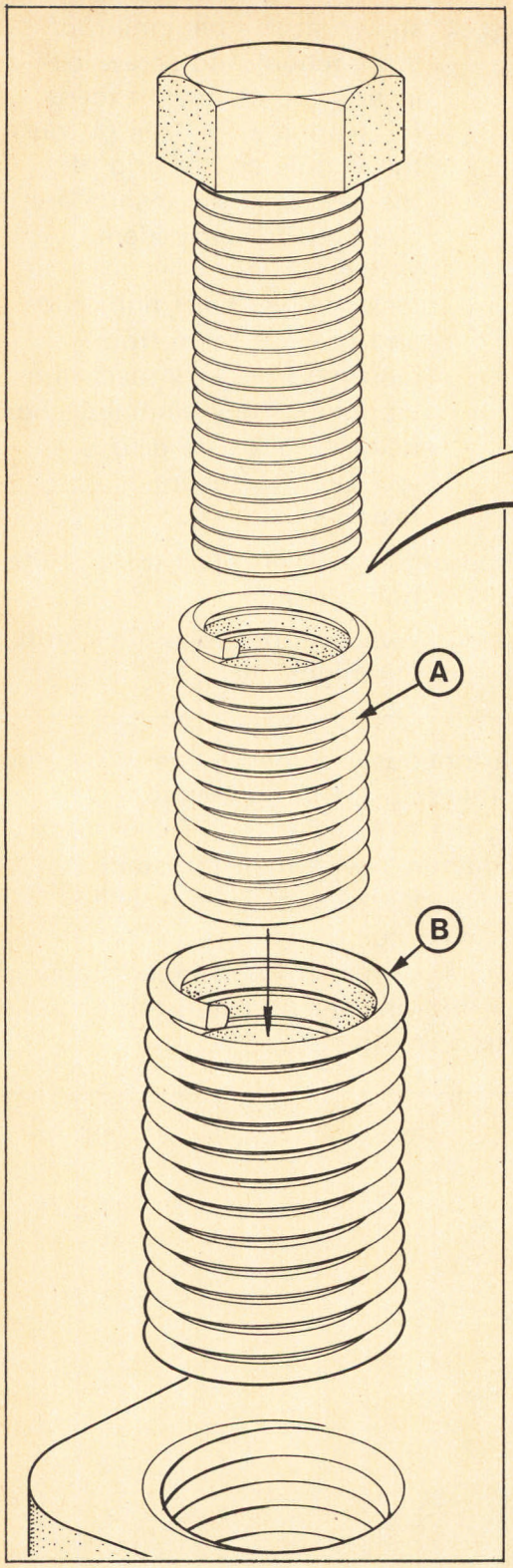


Holes that have been erroneously tapped oversize may be restored to original size by retapping with an oversize bottoming tap and installing the oversize insert. These inserts are made of slightly larger diameter wire than the standard insert and are marked for easy identification with a yellow marking on the tang (A) and first coil (B).

If the hole has been damaged and is egg-shaped, tapered or even bell-mouthed, it can be repaired by using the oversize insert. (For further information, see page 115.)

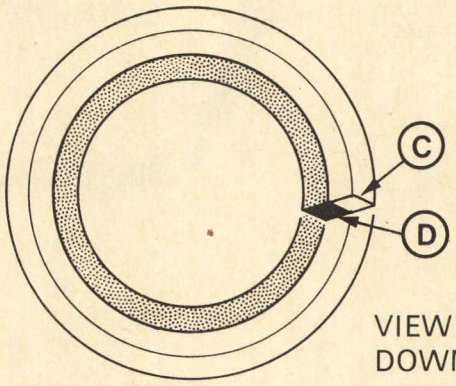


TWINSERTS



Twinserts consist of two inserts, an outer insert (B) and an inner insert (A). Twinserts are recommended for restoring tapped holes that have been stripped, are off center or damaged.

The twinsert should be used when the hole is beyond the corrective range of the oversize insert (discussed on previous page).



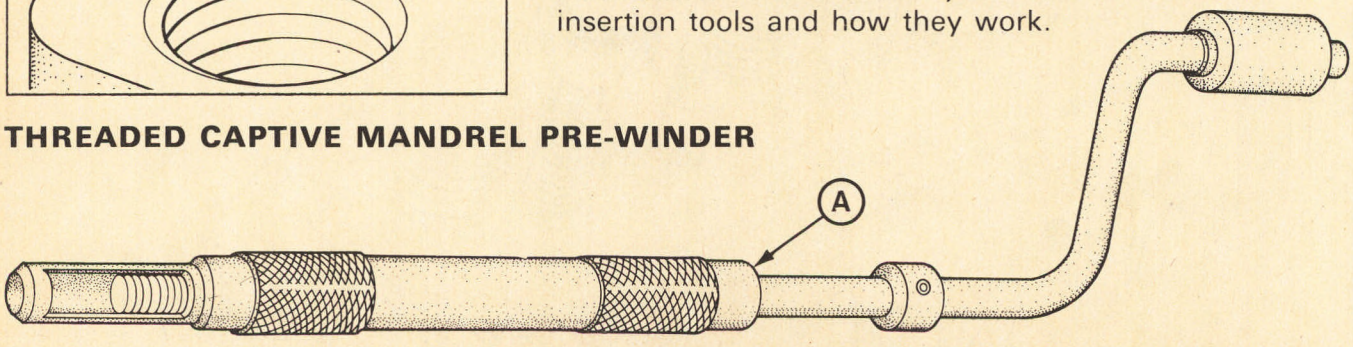
VIEW LOOKING DOWN

1. Drill and tap hole (per Heli-Coil Corporation instructions).
2. Remove any chips in hole before installing new insert.
3. Install outer insert (B) to correct depth (¼ to ½ turn below surface of hole).
4. Break tang of outer insert off with tang break-off tool.
5. Install inner insert (A).
6. Position end (D) of inner insert flush with end (C) of outer insert.
7. Break tang of inner insert off with tang break-off tool.

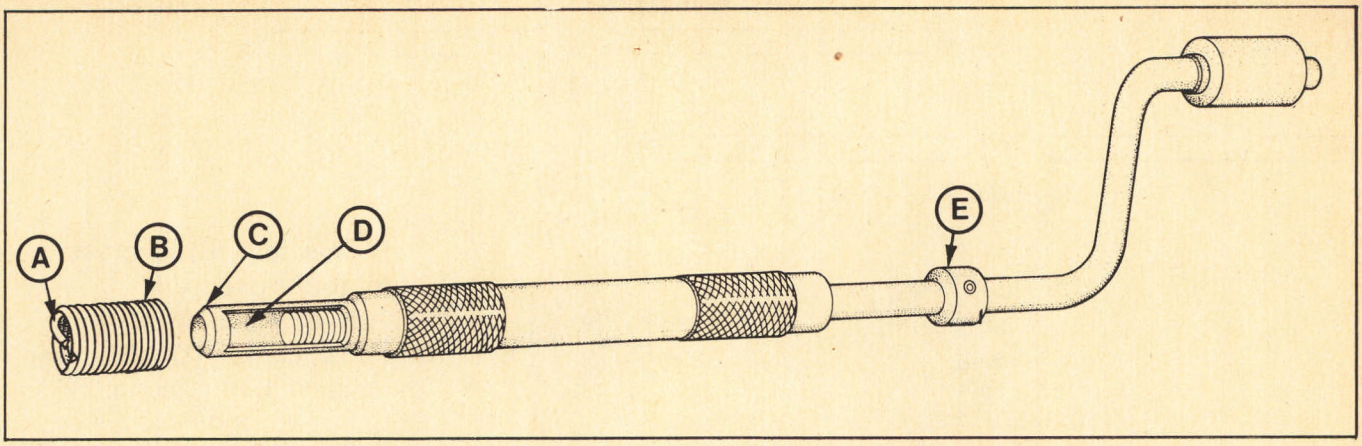
THREAD INSERT INSTALLATION HAND TOOLS

Normally, the Heli-Coil Corporation will supply the proper size tap and the installation tool in addition to the Heli-Coil insert in kit form (called ''Master Thread Repair Kits'') for installing the insert. The following information will familiarize you with the different insertion tools and how they work.

THREADED CAPTIVE MANDREL PRE-WINDER



This tool (A) is used with inserts of national coarse (NC) and national fine (NF) threads from a No. 4 through ½-inch nominal (not actual) diameter.



1. Place insert (B) in chamber (D) with tang (A) facing forward.

2. Place finger lightly over insert and rotate mandrel (C) through the insert until only one thread of insert is exposed beyond tip of mandrel.

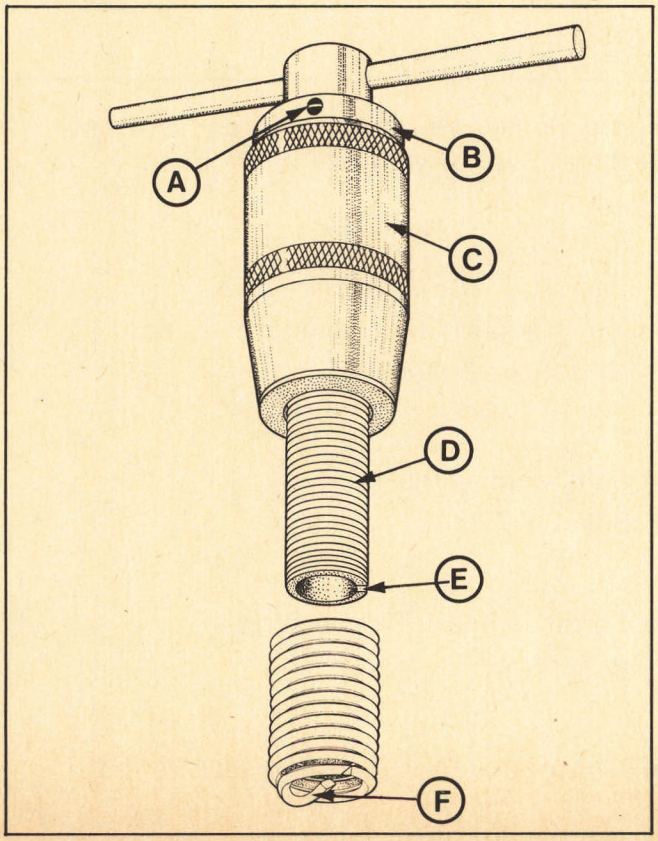
3. Adjust depth control stop nut (E) for desired depth you wish insert to go.

4. Place tool squarely against tapped hole. Wind insert in until stop nut (E) is contacted.

5. Retract mandrel by rotating counterclockwise.

THREADED NON-CAPTIVE MANDREL

This tool is used only with inserts of national fine (NF) threads above ½-inch in diameter.



1. Keeping pre-winder body (C) in contact with stop collar (B), loosen set screw (A).

2. Slide mandrel (D) forward until it projects from the body (C) a distance equal to the insert length.

3. Tighten set screw (A).

4. Remove body (C).

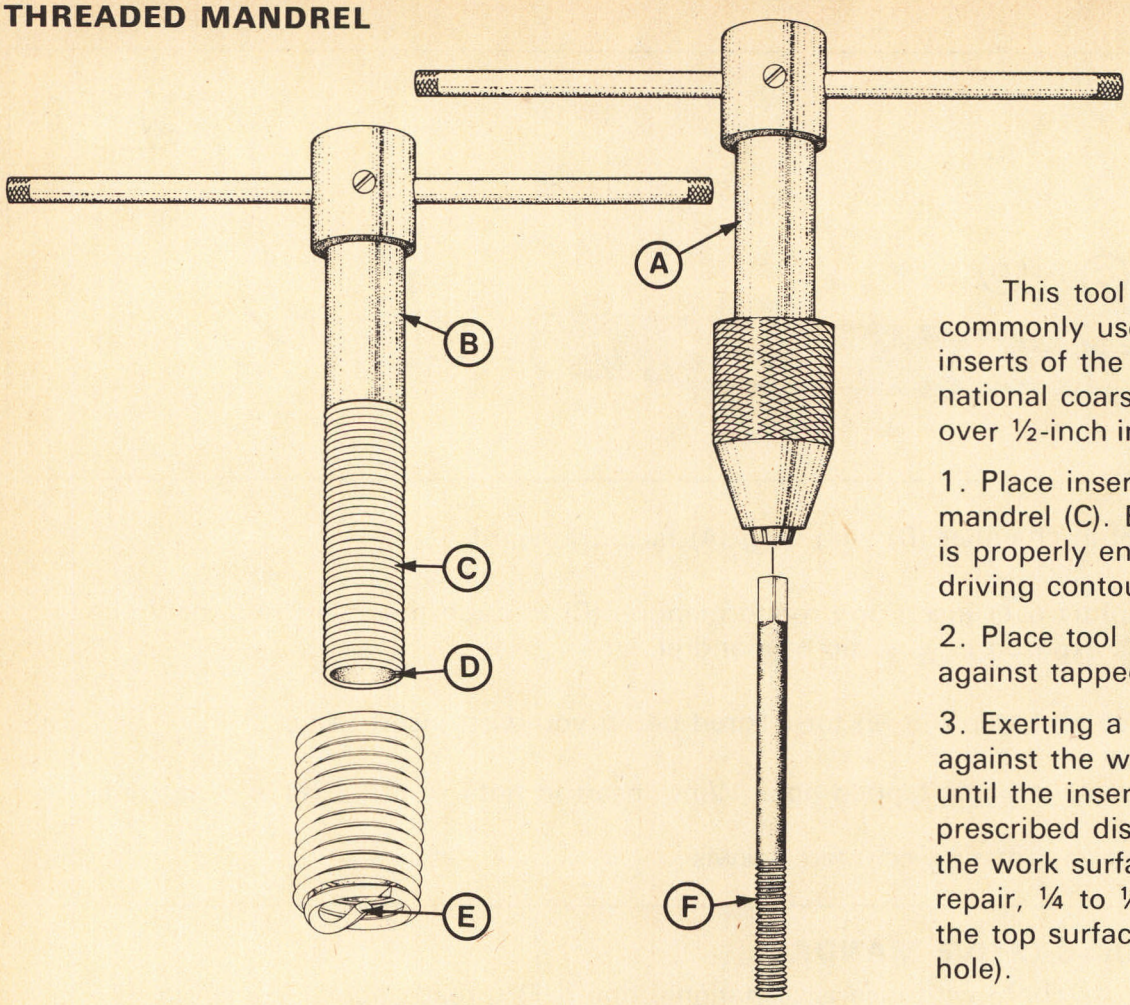
5. Place insert on mandrel (D). Be sure tang (F) of insert is engaged in driving contour (E) of tool.

6. Install body (C).

7. While holding body (C), wind insert into hole until top shoulder of insert contacts body. (Correct depth of insert should be ¼ to ½ turn below surface of hole).

8. Readjust depth, if necessary.

THREADED MANDREL



This tool (B) is most commonly used with inserts of the unified national coarse (UNC) thread over ½-inch in size.

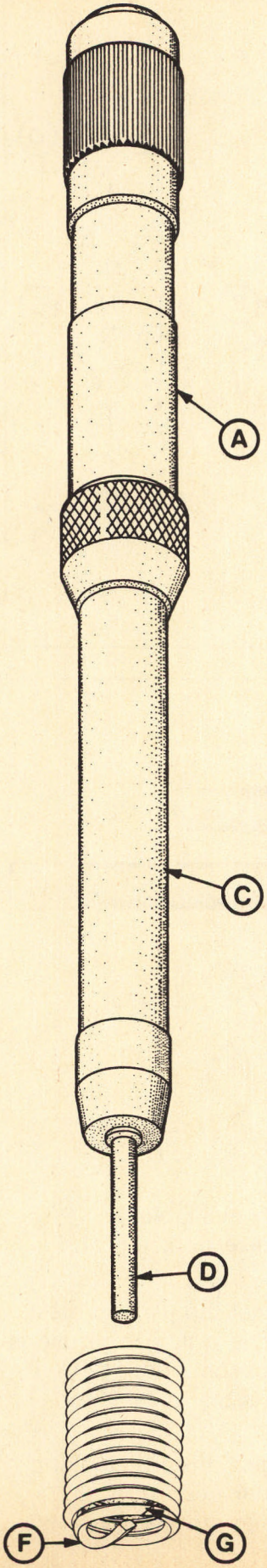
1. Place insert on threaded mandrel (C). Be sure tang (E) is properly engaged in driving contour (D) of tool.
2. Place tool squarely against tapped hole.
3. Exerting a slight pressure against the work, rotate tool until the insert is located the prescribed distance below the work surface (for normal repair, ¼ to ½ turn below the top surface of tapped hole).

Insertion tool (F) works exactly as described above except a regular tap handle (A) must be used to rotate the tool. (This type of tool [F] is supplied with the Master Thread Repair Kits when ordered from the Heli-Coil Corporation.)

The following is a list of bulletins which will be sent to you free upon request from the Heli-Coil Corporation. These bulletins have a great deal of valuable information on thread inserts and their use:

- Screw Thread Inserts—Design and Production—Bulletin 900.
- Screw Thread Repair Kits—Bulletin 830.
- Oversized Inserts and Twinserts—Bulletin 843.
- Stud Locking Inserts—Bulletin 842.
- Inserts for "0" rings—Bulletin 753.
- Industrial/Military Screw Insert and Tool Kits—Bulletin 901.
- Self-Tapping Inserts—Bulletin 772-A.
- Serrated Spark Plug Inserts—Bulletin 804.
- Metric Size Inserts—Bulletin 870.

TANG BREAK-OFF TOOLS



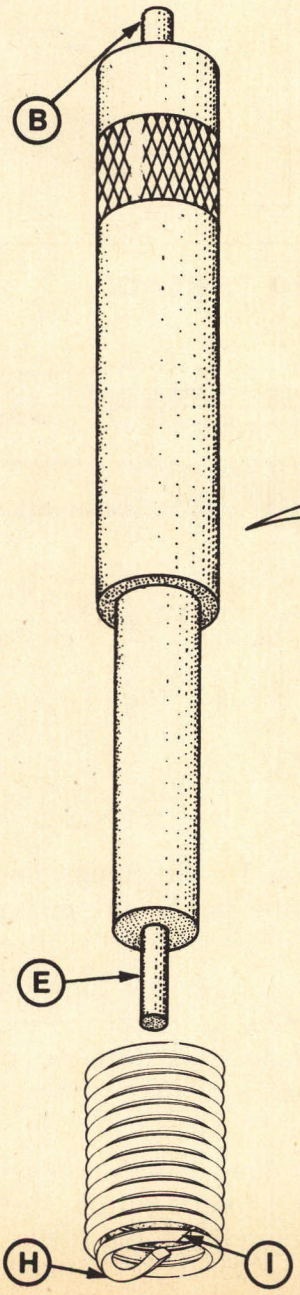
AUTOMATIC BREAK-OFF TOOL

The automatic tool (C) is used on inserts up through ½-inch in size.

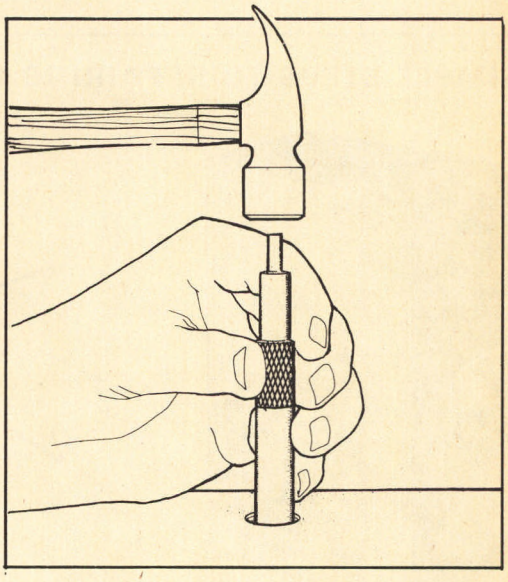
In blind holes (holes that are not drilled through), the tangs of the insert may be removed, when necessary, if the hole is deep enough to allow the tang to be broken off.

In holes that have been drilled through, the tang should always be removed after installation.

The automatic break-off tool works alone to remove the tang of a threaded insert without the need of a hammer. It has a spring-loaded sleeve which actuates the punch, causing it to strike a uniform blow against the tang (F). It can be operated with one hand.



1. Place punch (D) of tool into the assembled insert until punch rests on tang (F).
2. Push barrel (A) down until tool clicks and tang snaps off at notch (G).



MANUAL BREAK-OFF TOOL

The manual tool is used on inserts from 9/16-inch through 1 inch and consists of a punch held loosely in a sleeve.

1. Place punch (E) of tool into the assembled insert until punch rests on tang (H).
2. Using a hammer, strike opposite end (B) of punch a sharp blow.
3. Tang (H) should break off at notch (I).

INSERT EXTRACTING TOOL

When it is necessary to extract an improperly installed or damaged insert, it will be necessary to use the insert extracting tool (A). Without this tool, it is almost impossible to remove a damaged insert.

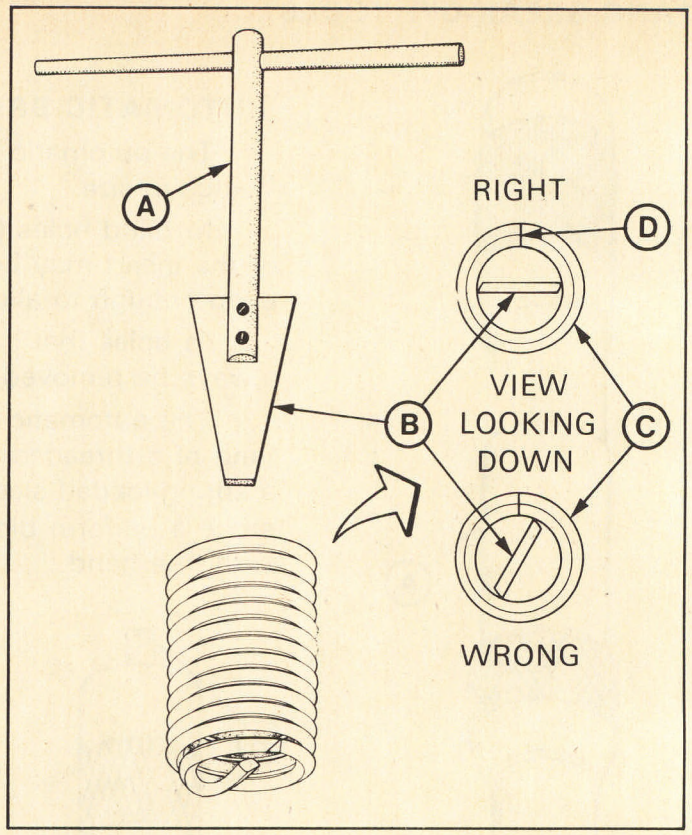
1. Place blade (B) of tool into the hole so that the blade is touching the first thread of the insert (C).

CAUTION

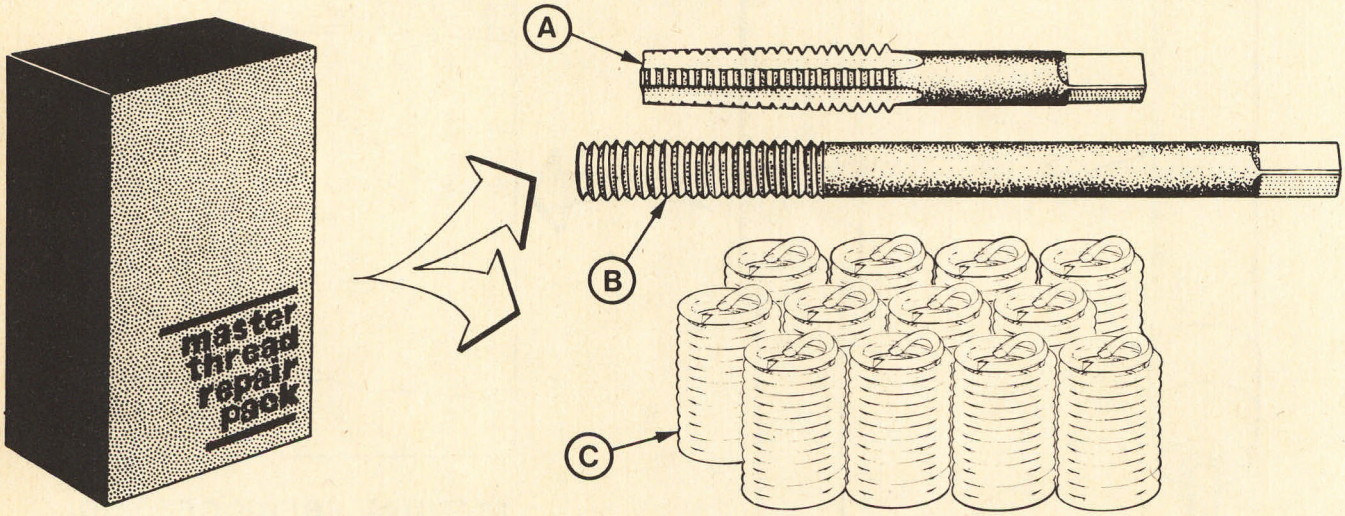
Be sure blade (B) is positioned in the insert at right angles to the insert tip end (D)

2. Using a hammer, strike handle end of tool a sharp blow, digging the blade into the top coil of the insert.

3. While pressing down on the handle of tool (A), rotate tool counterclockwise until insert is removed.



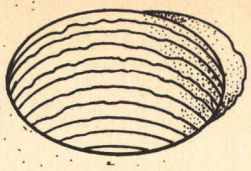
SIMPLE STEPS TO REPAIRING DAMAGED THREADS



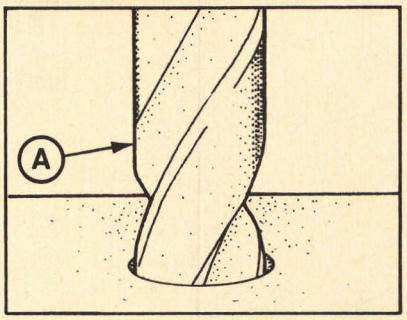
As mentioned earlier in this section, Master Thread Repair Packs are available from the Heli-Coil Corporation and really take the guesswork out of the size drill, tap and insert to use when making insert repairs.

The kit contains the insertion tool (B), the correct size high-speed steel tap (A), stainless steel inserts (C) and complete instructions on how to install the insert. (The drill size to use is stated on the kit box.) The kits come in all thread sizes, foreign and domestic. The Heli-Coil Corporation will send free upon request any needed charts showing drill sizes in relation to tap and insert sizes.

The following simple steps will show how easy it is to repair damaged threads, making them stronger than the original thread, assuring freedom from thread wear even after repeated disassembly and reassembly and eliminating thread failure due to stripping, vibration, fatigue, corrosion or seizing:



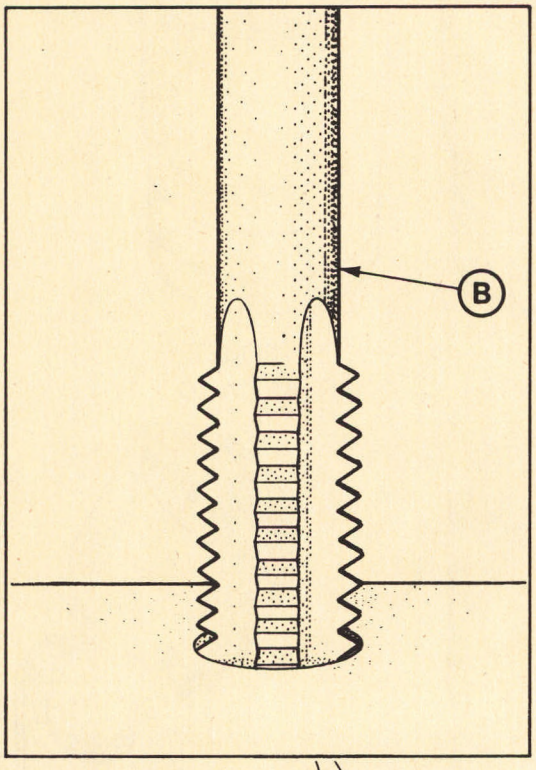
Hole stripped and damaged.



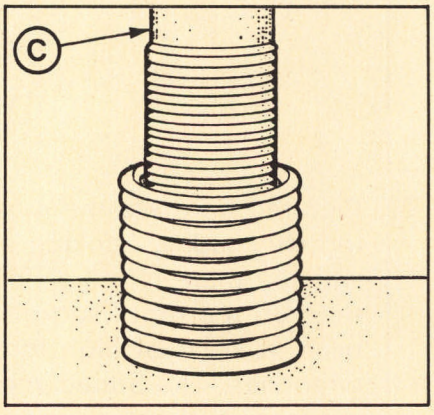
Using proper size tap drill (A), drill damaged hole. Clean out all chips from the hole before using tap.

CAUTION

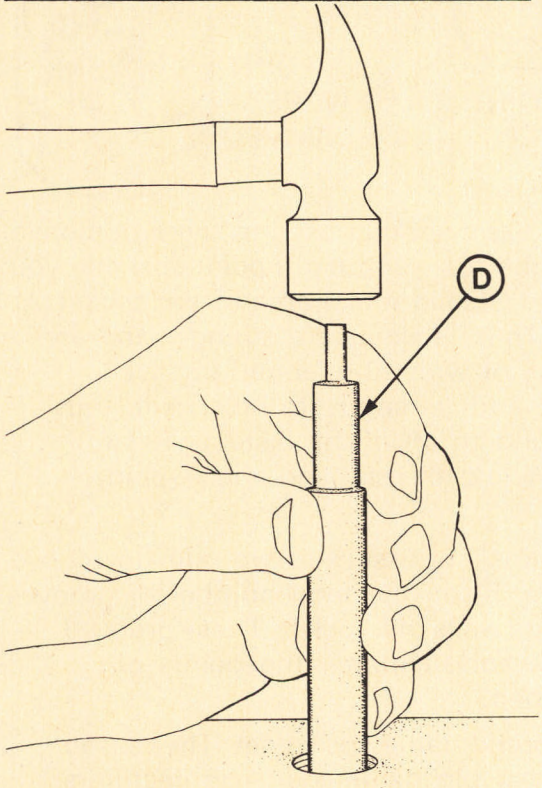
Never tap a hole that already has a thread insert in it. The tap may bind and break off, and damage to the material the insert is in will result.



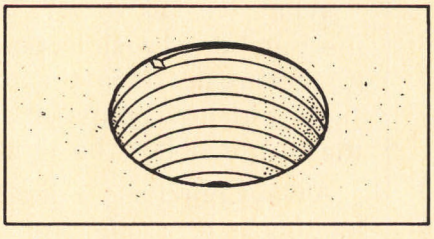
If the hole already has a damaged insert in it, use the insert extracting tool (described earlier in this section) to remove it. Tap hole (B) to accept the thread insert. Clean out all chips from hole before attempting to install new insert.



Using insertion tool (C), install new thread insert in hole.



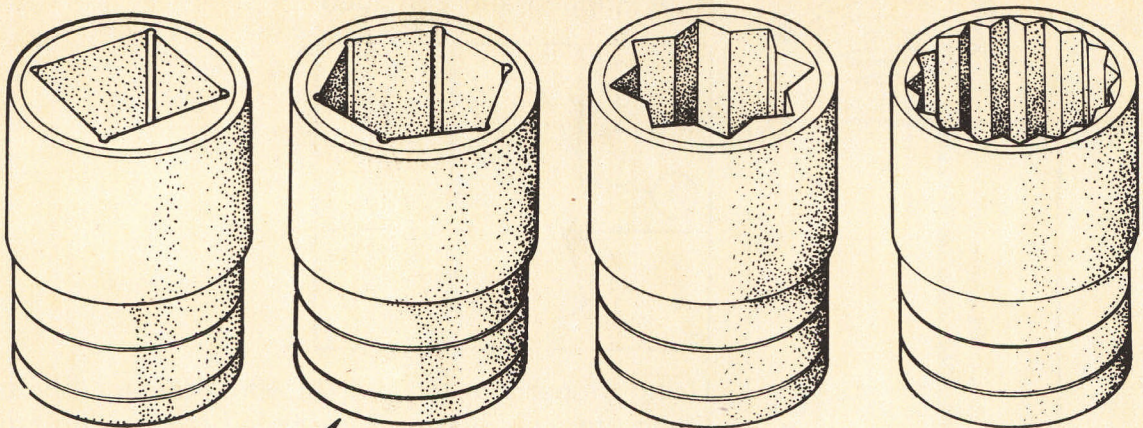
Using tang break-off tool or punch (D), remove tang from new thread insert.



Result: A new threaded hole ready for use and stronger than ever.

The thread insert is a professional way to repair damaged threads in most pieces of equipment. Many professional race drivers today add thread inserts to their engines even though no existing thread damage exists. The racer's engine is disassembled and assembled many times before he actually goes onto the track for the big race. With the high speeds and vibration that exist during a race, no driver can afford to have any fastener come loose.

SOCKETS

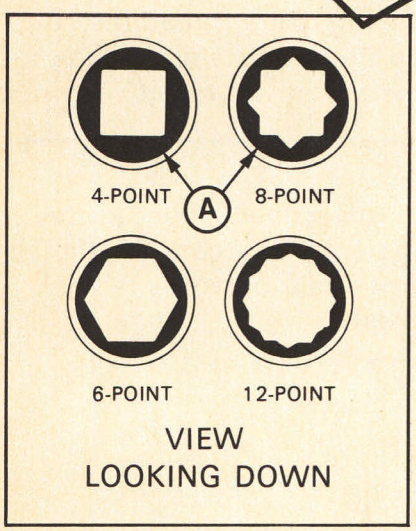


4-POINT STANDARD

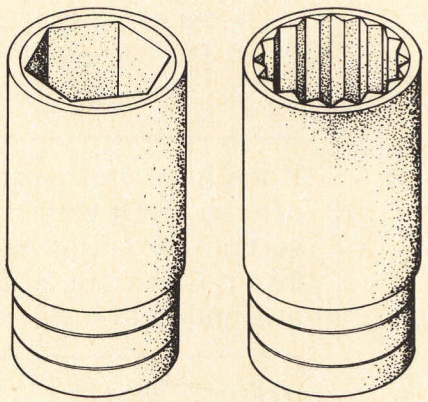
6-POINT STANDARD

8-POINT STANDARD

12-POINT STANDARD

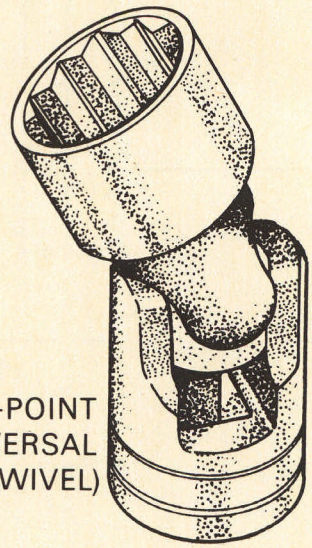


VIEW LOOKING DOWN

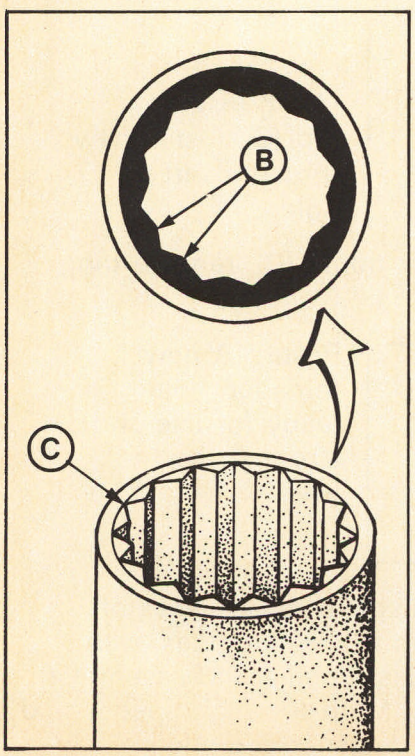


6-POINT DEEP

12-POINT DEEP



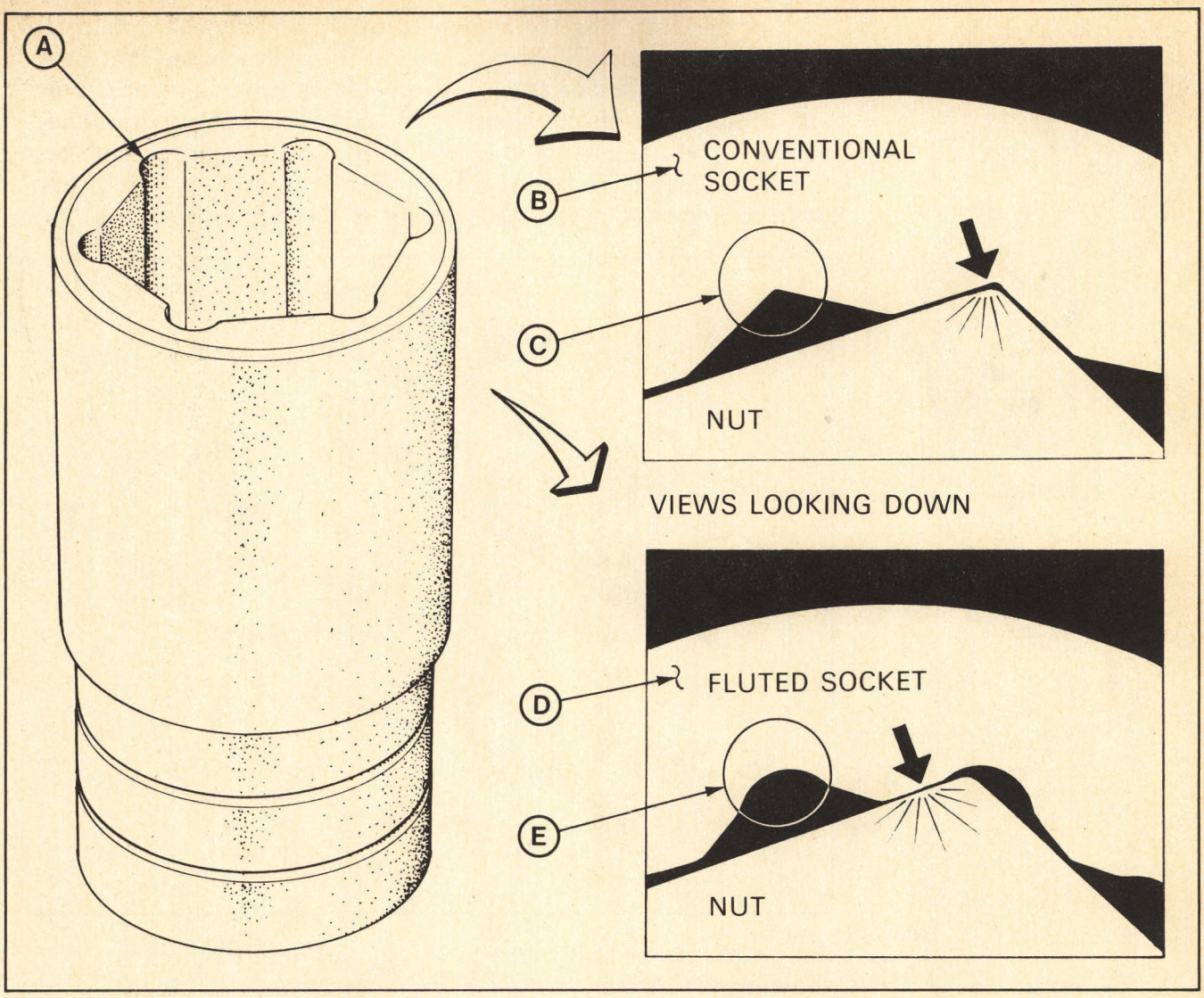
12-POINT UNIVERSAL (OR SWIVEL)



Pictured here are the most basic sockets used in the automotive industry today. Looking at the four- and eight-point sockets, you will see there is more "meat" (solid metal area of the socket (A) than on the other sockets. These sockets are stronger and are used in areas of high torque or with air-operated impact wrenches. The added meat adds strength to the socket, thus preventing slipping and rounding off of the fastener head. However, for most general work, the six- and twelve-point sockets are best.

When we talk about "points" of a socket, we refer to the number of visible points (B) on the total number of grooves (C) that are cut down the inside walls of a socket. These grooved high and low points of the socket match the points of the nut or bolt to be tightened.

Always purchase a good brand name socket set. The reason for this is a simple one. Most big name tool manufacturers are in business for only one thing, and that is to produce tools. They take great pride in design and engineering and use the best alloys available for strength. Some manufacturers even go so far as to guarantee their tools against breakage for the life of the tool. Shop around and compare.



An important feature to look for in well-made sockets is how the socket's inside walls (A) are reamed or bored.

The conventional socket (B) has deep-pointed grooves (C) bored down the inside wall of the socket. Note how the corner of the conventional socket (B) contacts the corner of the nut, causing greater stress to the socket and to the fastener. This is fine provided your socket and the nut are new and you do not plan to apply too much torque to the fastener.

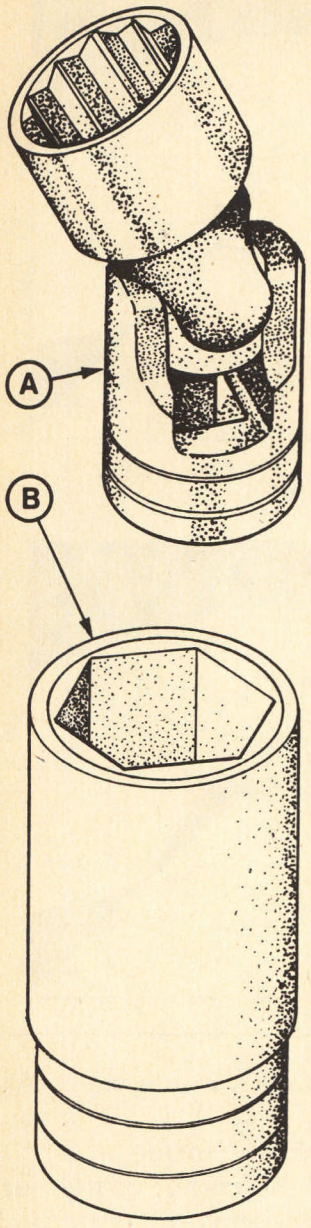
The fluted socket (D) (fluted is a cut furrow or channel)(E) contacts the nut away from the corner, thus cutting down on nut distortion and distributing the stress over a larger area of the nut. The fluted socket also allows you to get on and off the fastener with greater ease, increases your socket life and prevents damage to nuts and bolts.

To buy cheap tools is a waste of time and money. Get the most for your money by purchasing quality brand name tools where expert engineering has gone into the material and design. Human factors engineers have studied tool design to give you the following:

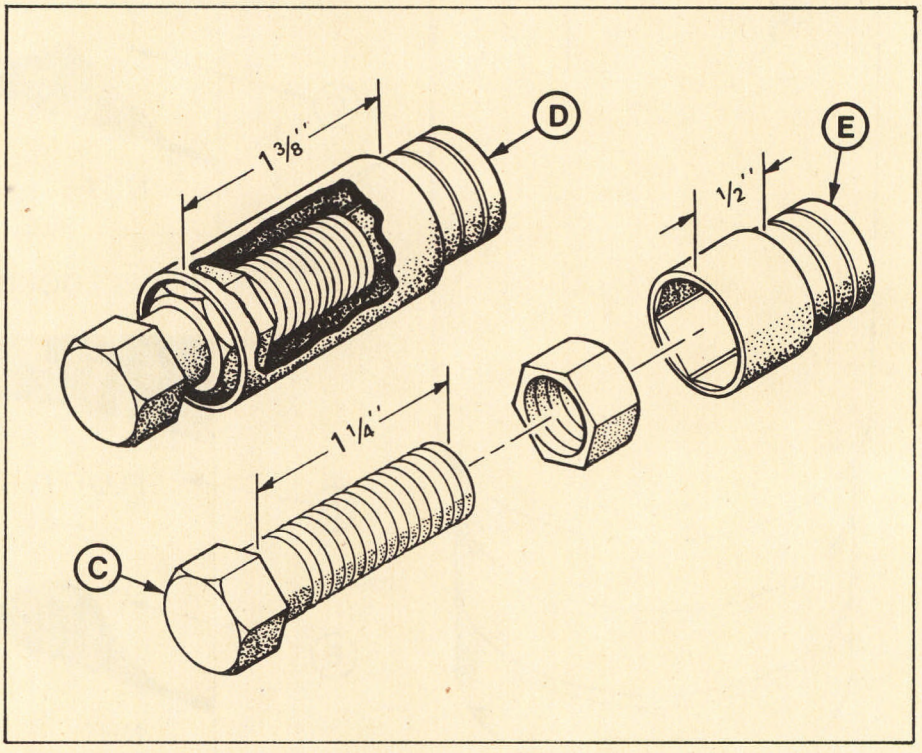
- Designs for maximum clearance and good grip.
- Tool plating, such as chrome, to allow the tool to be cleaned easily and add to the tool's life.
- Sealed ratchet heads to prevent dirt and grime from entering the ratchet mechanism and causing excessive wear.
- Use of high-grade steels of different alloys to obtain the most desirable qualities of hardness and toughness in every part.

Each socket in a set is sized to fit a nut or bolt of a given size. The size of each socket is stamped near the base of the socket.

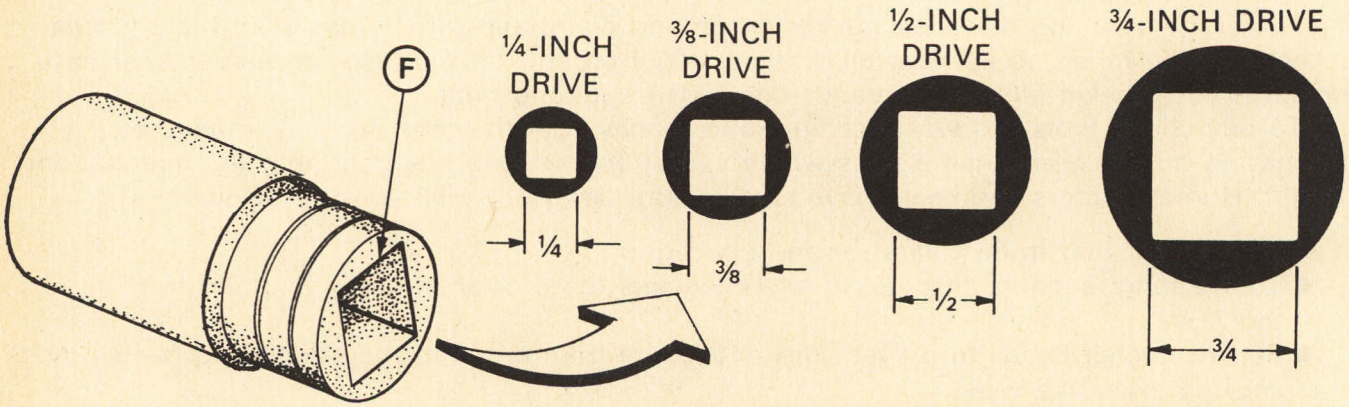
SOCKETS



Socket wrenches are similar to other wrenches in application but have more uses. Sockets can reach into recesses that other wrenches cannot. For speed in removals and installations, they are unmatched. The universal or swivel socket (A) permits the socket to be used at various angles by the swiveling action of the socket head. The deep socket (B) not only adds length to your socket handle or extension but is basic to loosening a

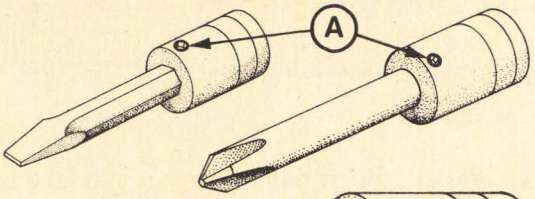


nut on a stud or bolt that has a large number of threads showing (C). A standard socket is approximately ½-inch deep (E). A deep socket is approximately 1⅜ inches deep (D), based on a ⅜-inch drive, 9/16-inch socket. Therefore it stands to reason you would use the deep socket to loosen the nut instead of the standard socket. If the standard socket were used, the stud end would bottom out on the head of your socket handle before the socket ever reached the nut.

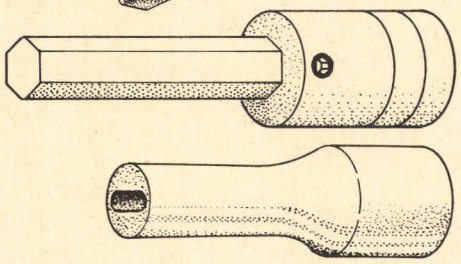


When we mention the "square drive" (F) of the socket, we are talking about the female square end, or the end of the socket that attaches to the socket handle. The square drives of a socket range from ¼-inch up to 2 inches for heavy industrial use. For most common jobs, though, the ¼-inch through ¾-inch sizes are best.

There are many different types of sockets in a variety of square drives on the market today which allow you to perform almost any job imaginable. The following are just a few of the most widely used:



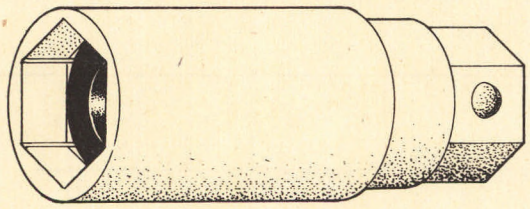
STANDARD AND PHILLIPS SCREWDRIVER SOCKETS: The screwdriver heads are interchangeable by removing either a roll pin or set screw (A). The screwdriver heads come in longs and shorts with a variety of blade widths and Phillips point sizes.

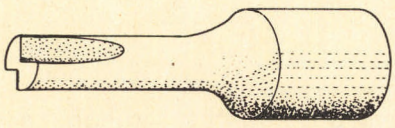


HEX-HEAD OR ALLEN-HEAD DRIVERS: These drivers are available in a complete set and in many different lengths and diameters.

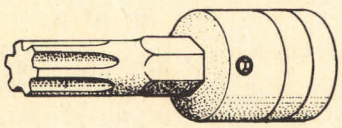
WINDSHIELD WIPER SOCKETS: This socket has an oval opening designed to fit oval-head screws used on many automobile windshield wipers.

SPARK PLUG SOCKET: This socket is designed to protect the ceramic covering and terminal of the spark plug by the use of a rubber insert inside the plug. The rubber grips the porcelain and prevents dropping and thus damaging the plug. As the rubber insert wears out, new ones are available. This socket is also great for removing mag wheel lug nuts. The depth of cut in the socket and the rubber insert prevent the socket from going on the nut too far and possibly scratching your chrome or mag wheels.

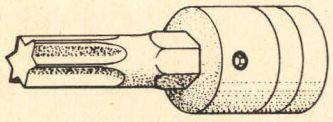




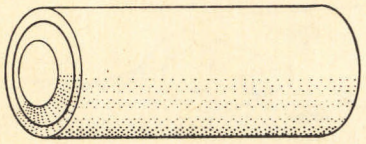
CLUTCH TYPE SCREWDRIVERS: This one is also known as the butterfly or the figure 8 because of its shape. Screws of this type are becoming increasingly popular in the automotive field.



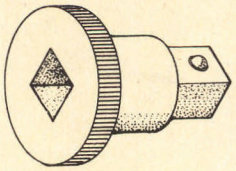
"TORX" DRIVER: This is used primarily to tighten the special fasteners that secure automotive seat belts and harnesses of late model automobiles. Drivers are interchangeable and come in a variety of sizes.



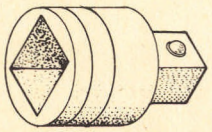
TRIPLE SQUARE SCREWDRIVER: Foreign cars such as Opel and Volkswagen use a fastener of this kind, making this socket a must. Drivers are interchangeable and available in a variety of sizes.



MAGNETIC SOCKET: Using this socket will convert your ratchet handle or extension into a magnet for retrieving metal parts from awkward places.



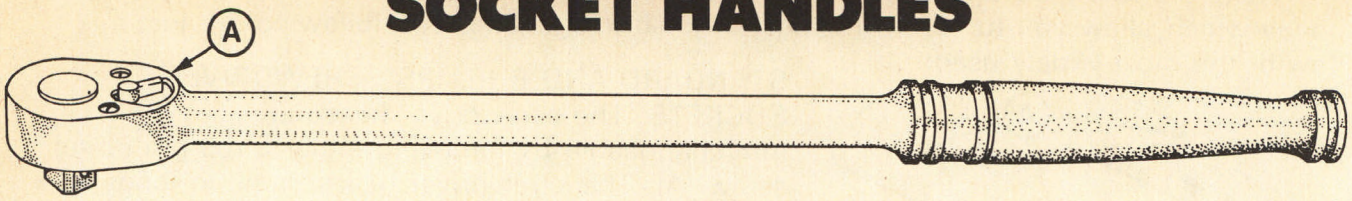
RATCHET SPINNER: This fits between ratchet and socket so nuts or bolts can be spun out fast by hand without having to move the ratchet handle. Great for close-quarters work.



ADAPTERS: There are many variations of adapters on the market which will allow you to adapt to any square drive possible. You can convert your ⅜-inch drive ratchet to ¼ drive or ½ drive, or your ½-inch drive ratchet to a ¾ drive, ⅜ drive or even a ¼ drive, etc.

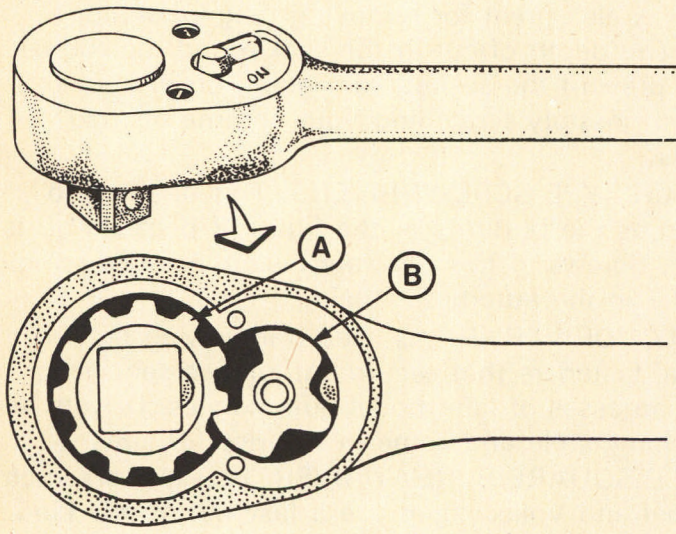
Naturally, all sockets are operated with some type of handle. Our next section, "Socket Handles," will discuss the most widely used socket handles on the market today. Using the proper socket handle with your socket will give you even more versatility when it comes to using sockets.

SOCKET HANDLES



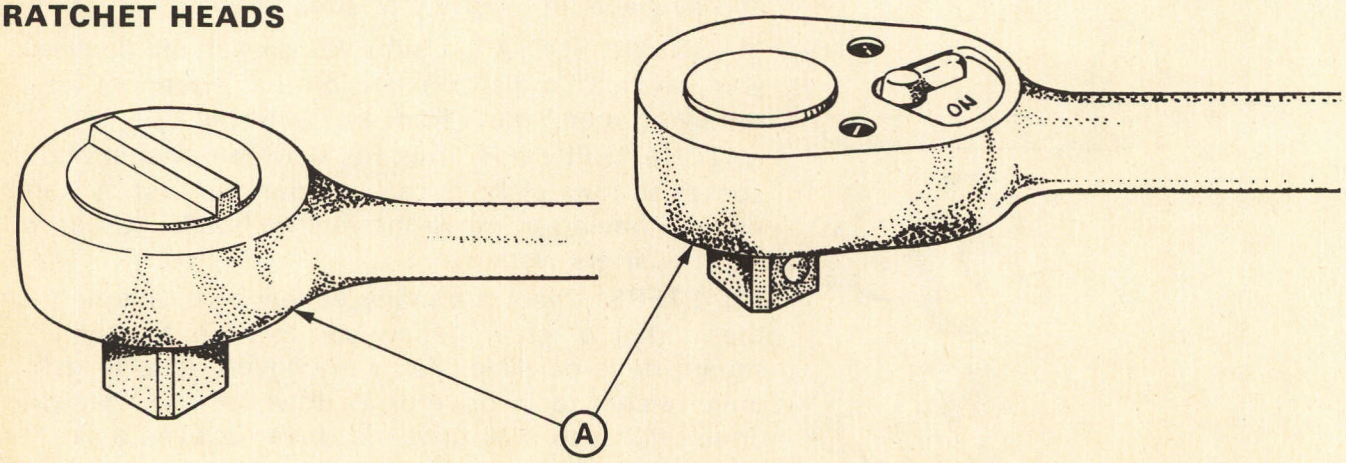
Pictured above is the reversible ratchet handle, which is one of the most commonly used in the automotive industry. This is just one of many different kinds of socket handles sold on the market today. As engines and machinery become more sophisticated, tool manufacturers have had to design new tool shapes and sizes to meet the mechanics' needs. Selecting the correct socket handles and sockets to match is very important if the job is to be done easily and correctly.

The ratchet handle is the most versatile of the socket handles discussed in this section. It allows the user to tighten or loosen a fastener without removing the socket from it, as must be done with the conventional open-end or box-end wrench. When the ratchet selector (A) is positioned to either the "tighten" or "loosen" position, the handle will "ratchet" on the back stroke and tighten or loosen the fastener on the forward stroke.



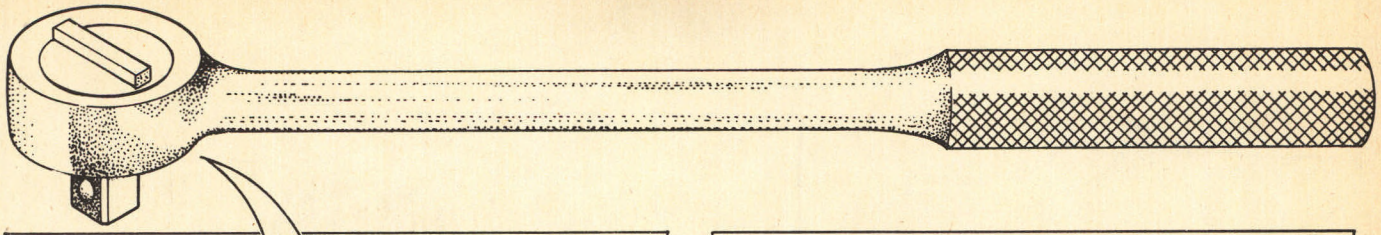
The word "ratchet" means a mechanism consisting of a notched wheel (A), the teeth of which engage a pawl (B), a hinged or pivoted member shaped to engage the teeth of the notched wheel which prevents motion of the wheel in one direction.

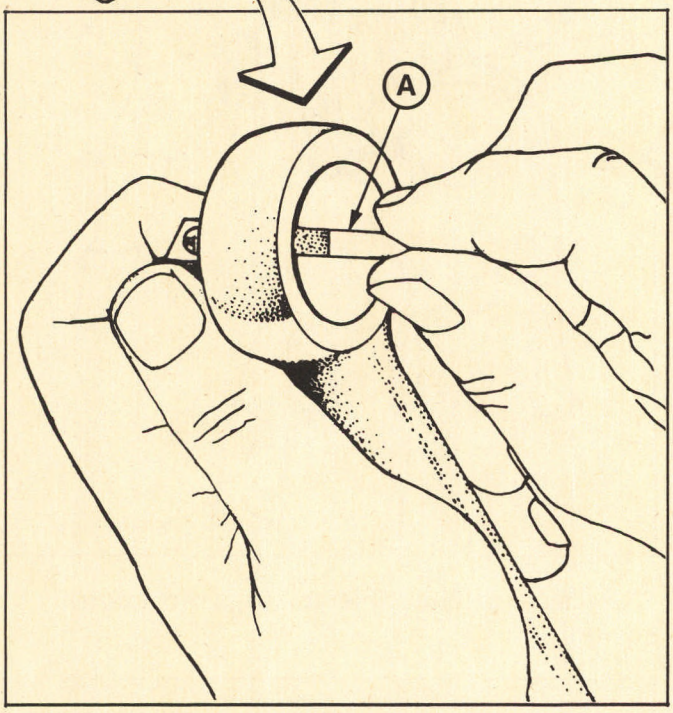
RATCHET HEADS



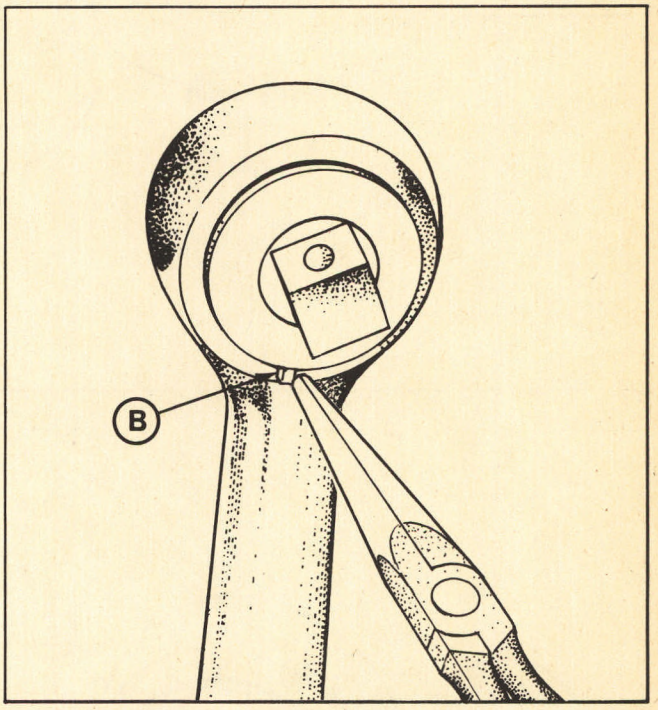
All ratchet heads (A) should be removed periodically for cleaning and lubrication. The only difference between ratchet heads is in their shape and method of removal, both of which we will now discuss.

TO REMOVE RATCHET HEAD:

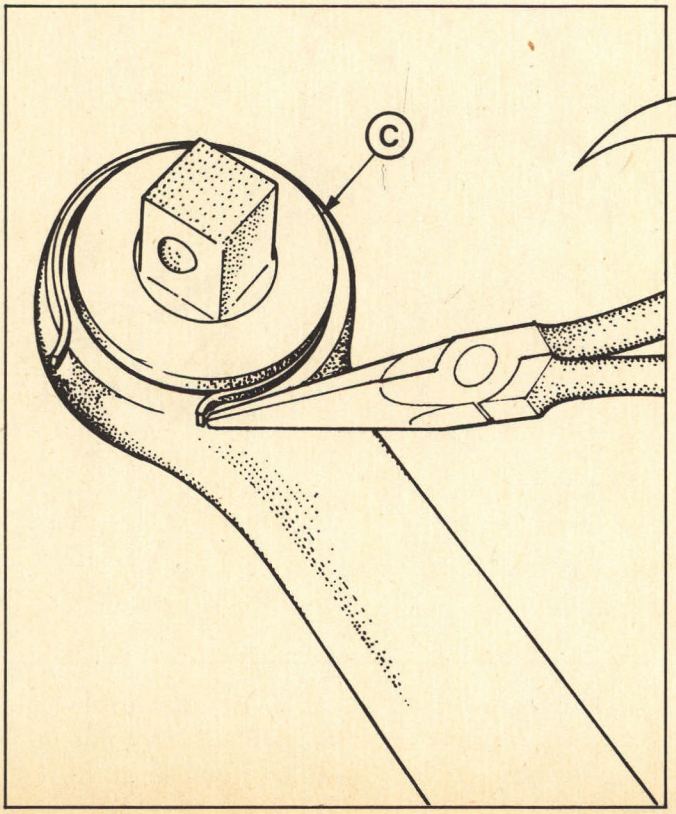


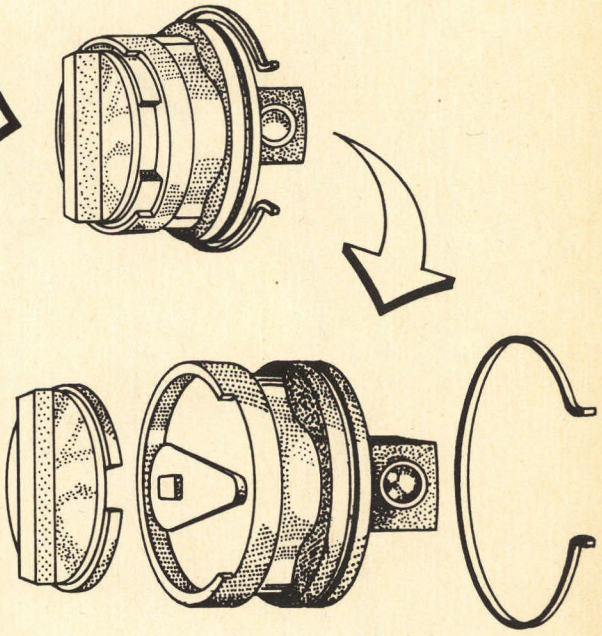


1. Place ratchet selector (A) in neutral position while holding square drive.



2. Compress snap ring (B) with a screwdriver or snap ring pliers.

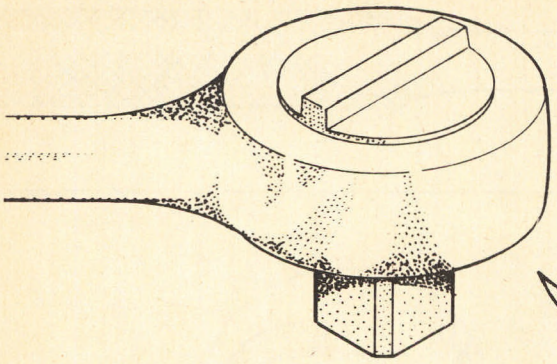


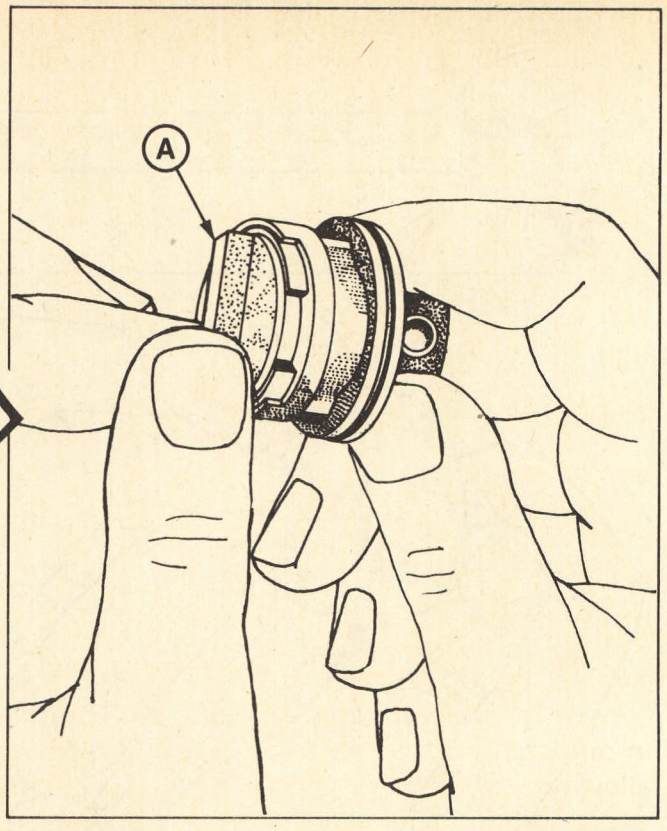


3. While compressing snap ring, gently strike back of ratchet on a solid surface. Release snap ring. Remove gear mechanism (C).

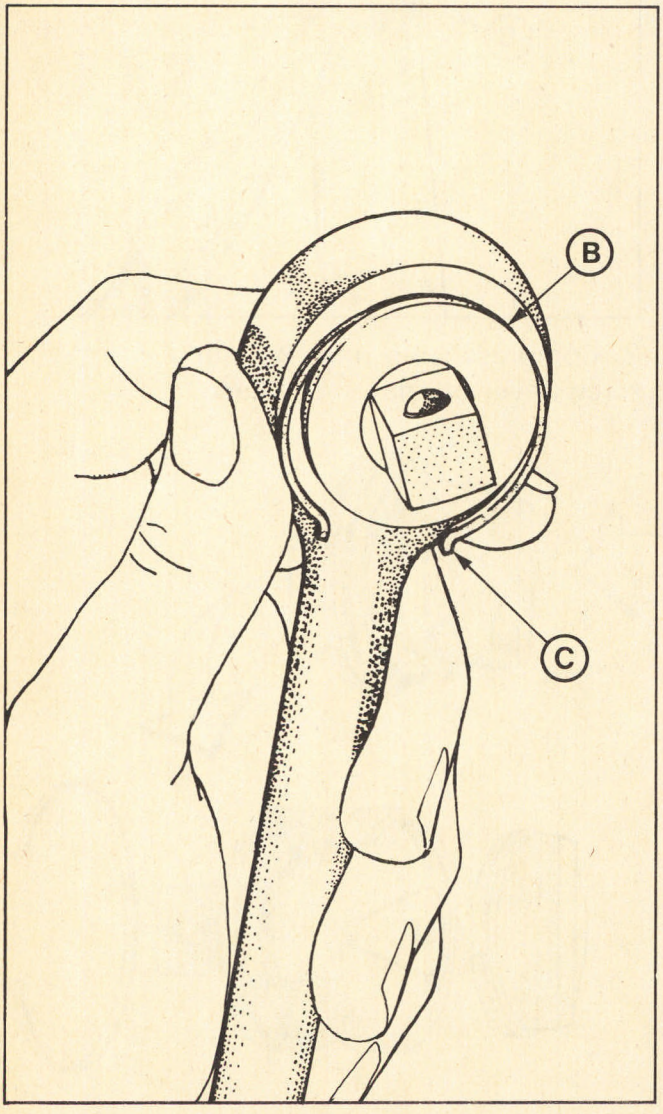
SOCKET HANDLES

TO INSTALL RATCHET HEAD:

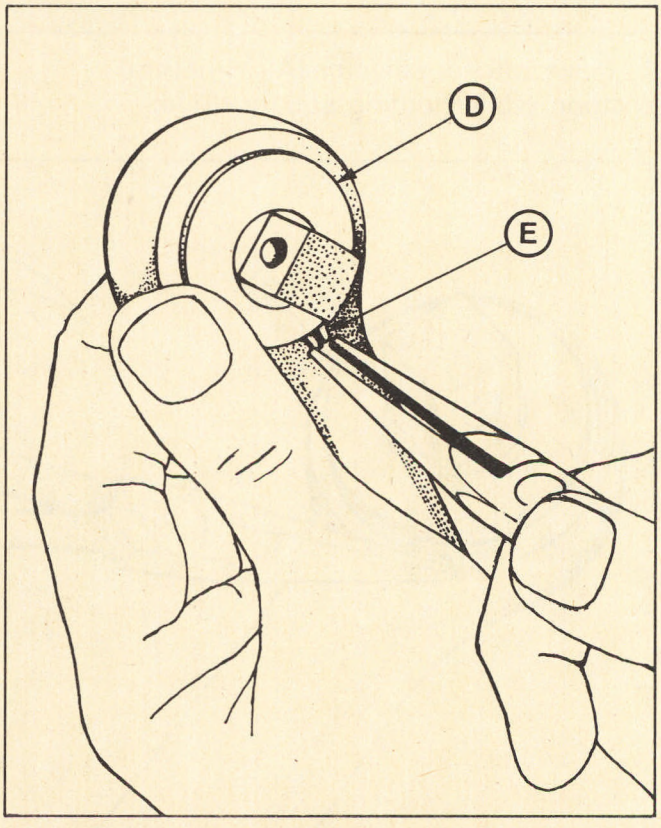




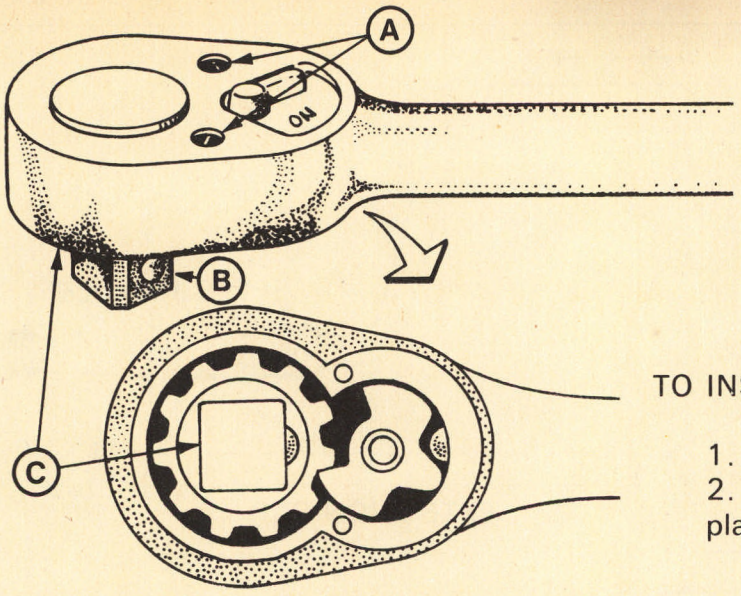
1. Be sure ratchet selector (A) is in neutral position.



2. Place gear mechanism (B) in handle. Place snap ring (C) in slot.



3. Using snap-ring pliers or needle-nose pliers, compress snap ring (E). Push gear mechanism (D) into handle. Release snap ring.



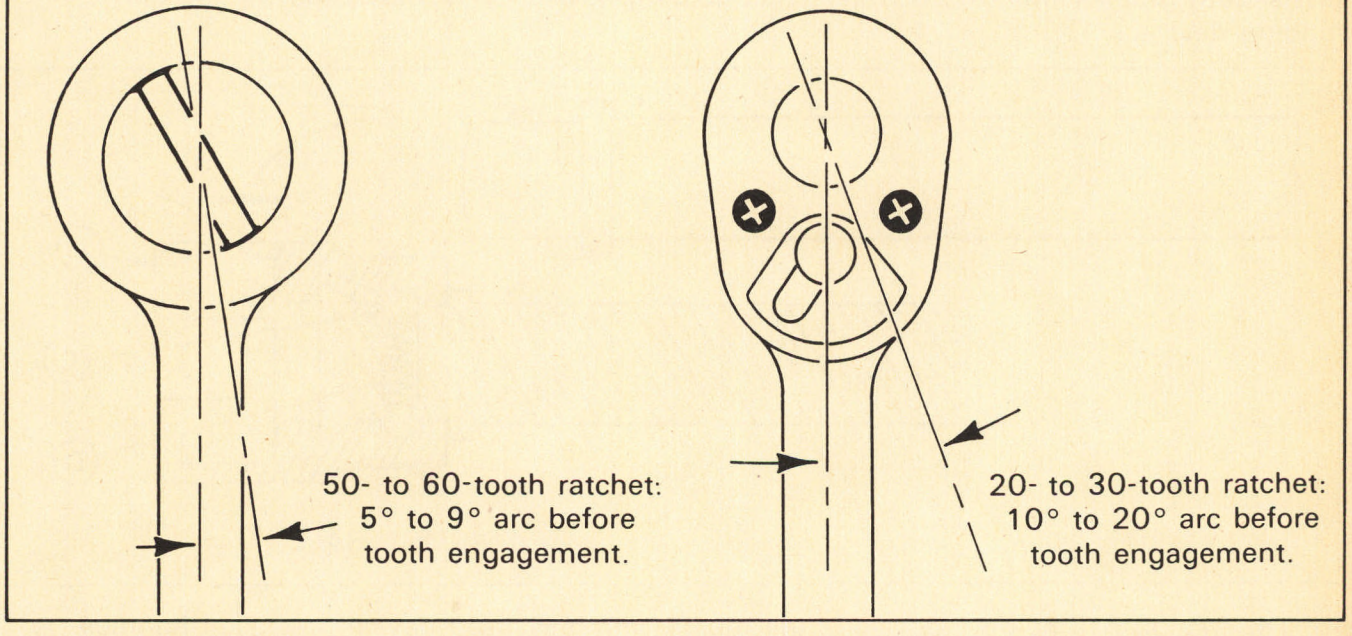
TO REMOVE RATCHET HEAD:

1. Remove two screws (A).
2. Gently tap square drive (B).
3. Remove gear mechanism (C).

TO INSTALL RATCHET HEAD:

1. Place gear mechanism (C) in handle.
2. While holding gear mechanism in place, install two screws (A).

The ¼-inch drive and ⅜-inch drive ratchets, which cover most standard jobs, should be chosen for the number of teeth in the gear mechanism. The more teeth (or number of clicks) in one complete revolution of the square drive, the smaller the turning radius becomes, thus allowing you to turn your ratchet in very close quarters. Most conventional ratchets have approximately 20 to 30 teeth on the gear mechanism, while some ratchets have as many as 60. As you can see, to get 60 teeth in the very small area of the gear mechanism means the teeth must be very close together. When working in such close quarters that you can only turn your ratchet approximately ¼-inch or less, this becomes very important in order to get that hard-to-get-to fastener tight.

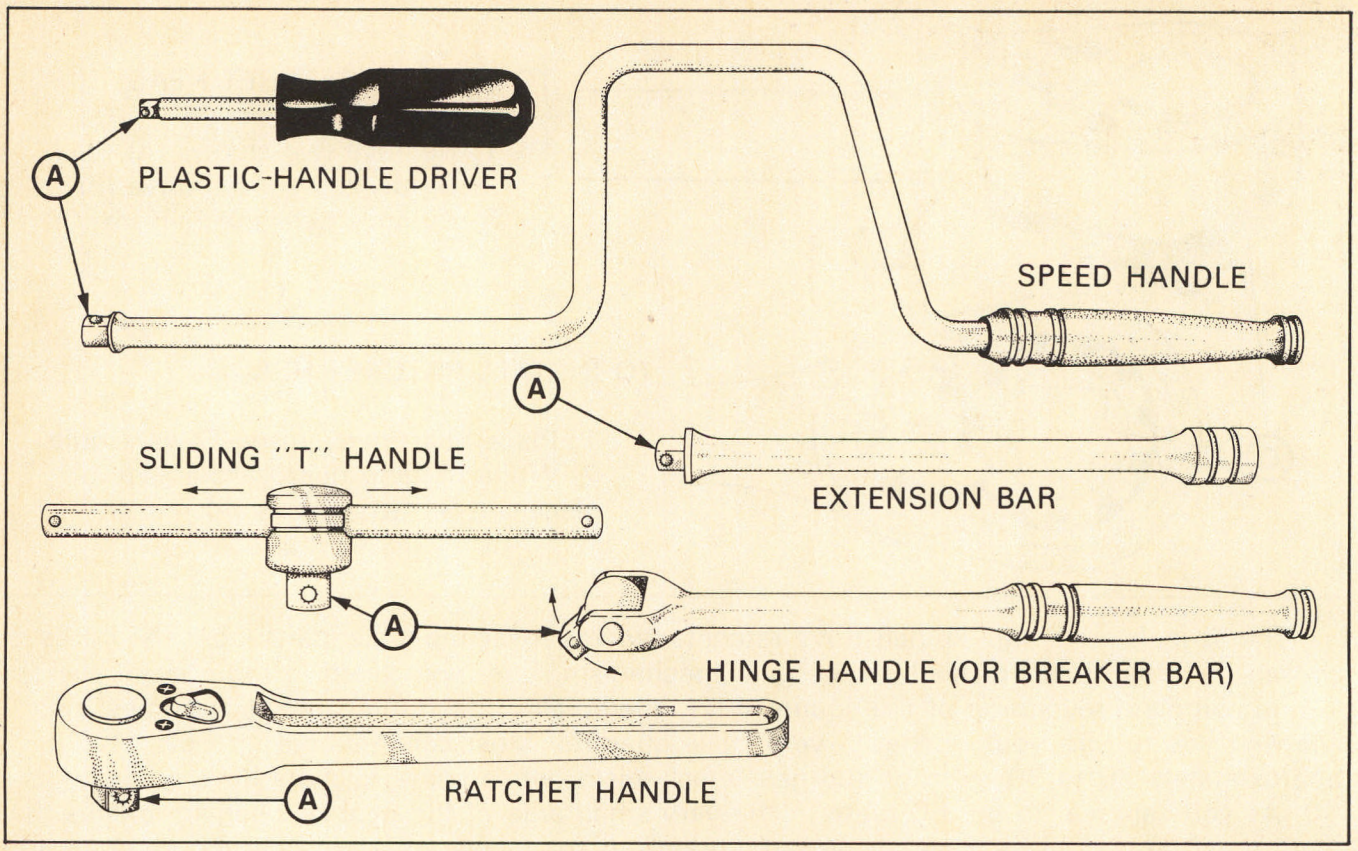


The ratchet with the greatest number of teeth per complete revolution will have little or no back-play, while the ratchet with 20 to 30 teeth may have as much as 5° to 10° back-play. This is due to the spacing between the teeth of the different ratchets.

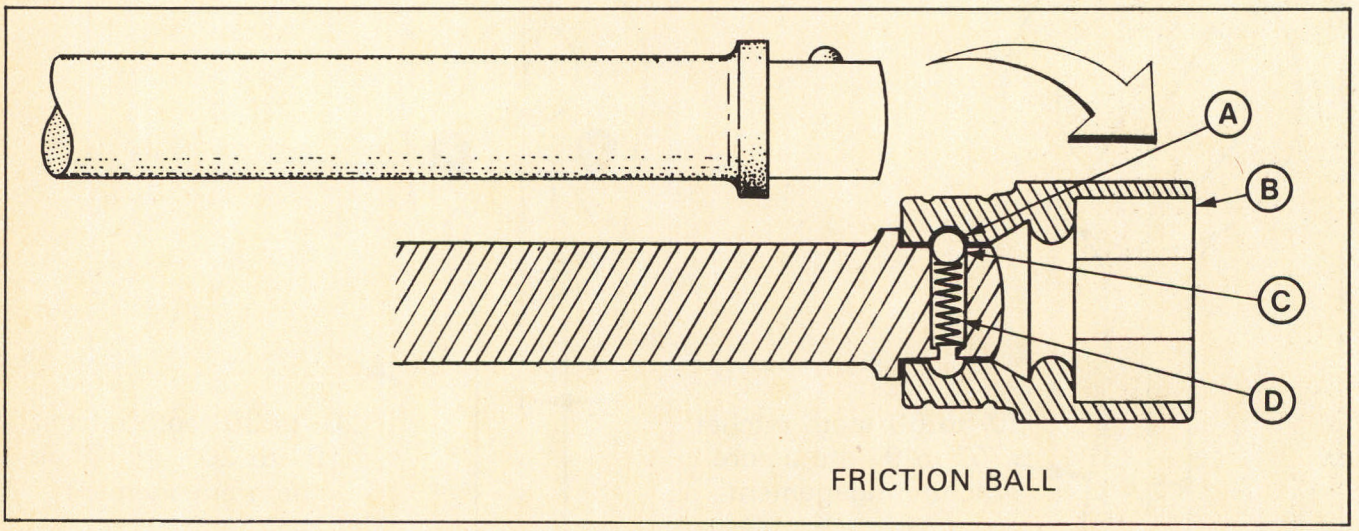
As the ratchets become larger in size (½-inch, ¾-inch and 1-inch square drives, etc.), the teeth in the gear mechanism have to be larger and fewer for strength purposes. Usually the larger ratchets will be used for heavy-duty jobs which require high torque and additional strength.

SOCKET HANDLES

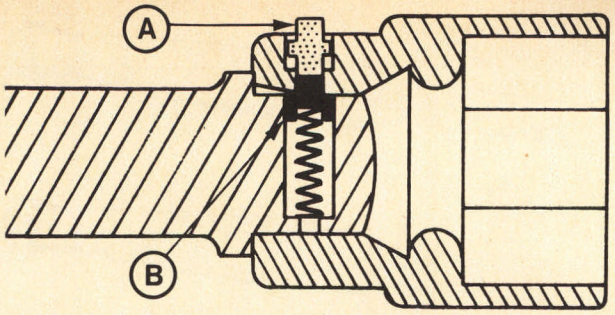
SQUARE DRIVES



The variety of socket handles pictured above all have one thing in common: the way the socket attaches to the square drive (A). As you can see, they all have a small, half-exposed ball bearing centered on one side of the square drive and held in place with a bushing insert just slightly smaller than the bearing. This holding device is known as the friction ball holding device.

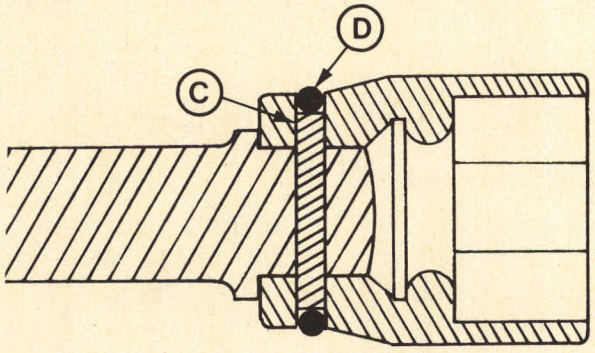


The friction ball holding device is the most commonly used device on socket handles today because of its ease and speed in changing sockets. As the socket (B) is pushed onto the socket handle, the ball bearing (C) is forced into a recess which compresses a return spring (D). When the socket is fully pushed onto the socket handle, a machined groove or mating hole (A), which *all* sockets have, aligns with the recessed ball bearing. The return spring forces the ball into the groove to hold the socket in place. A quick, sharp pull on the socket overrides the spring pressure on the ball bearing, forcing the socket over the ball and off the socket handle.

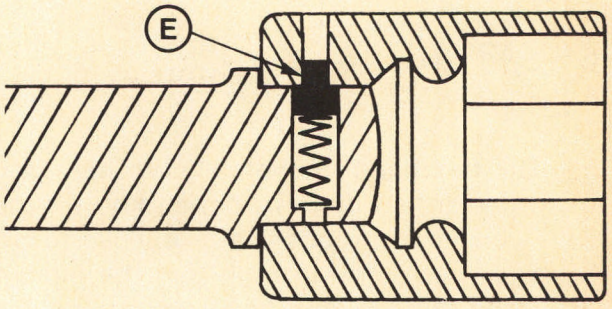


SOCKET RELEASE BUTTON

Another method of socket release is the manually-operated button (A). Instead of using the ball bearing on the socket handle as a holding device, a spring-operated button (B) is used. This type of release mechanism operates just like the friction ball release mechanism except that to release the socket from the socket handle, the button (A) must be depressed.



PIN AND RING



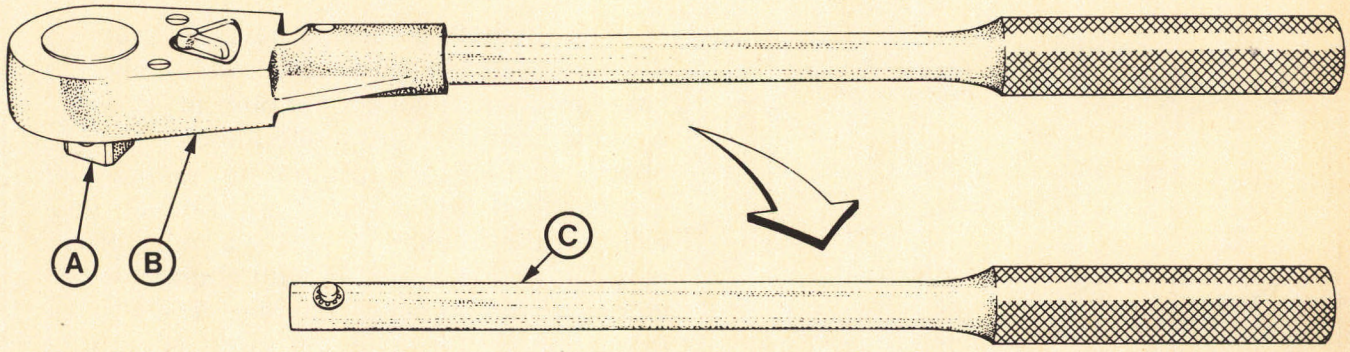
LOCKING BUTTON

Two other types of locking devices used primarily with power impact tools for additional strength are the pin and ring and the locking button types. With the pin and ring type, the socket handle has a hole drilled through the square drive. The socket is placed on the socket handle and a steel or rawhide pin (C) is inserted through the socket and the socket handle. A rubber band (D) is placed in the groove around the socket to hold the pin in place.

The locking button release mechanism has a spring-operated button (E) built into the socket handle and can only be released by depressing the button with a small rod or punch and pulling on the socket.

The following are just a few of the more commonly used socket handles in the automotive industry today. As you will see, there is a socket handle built for almost any job.

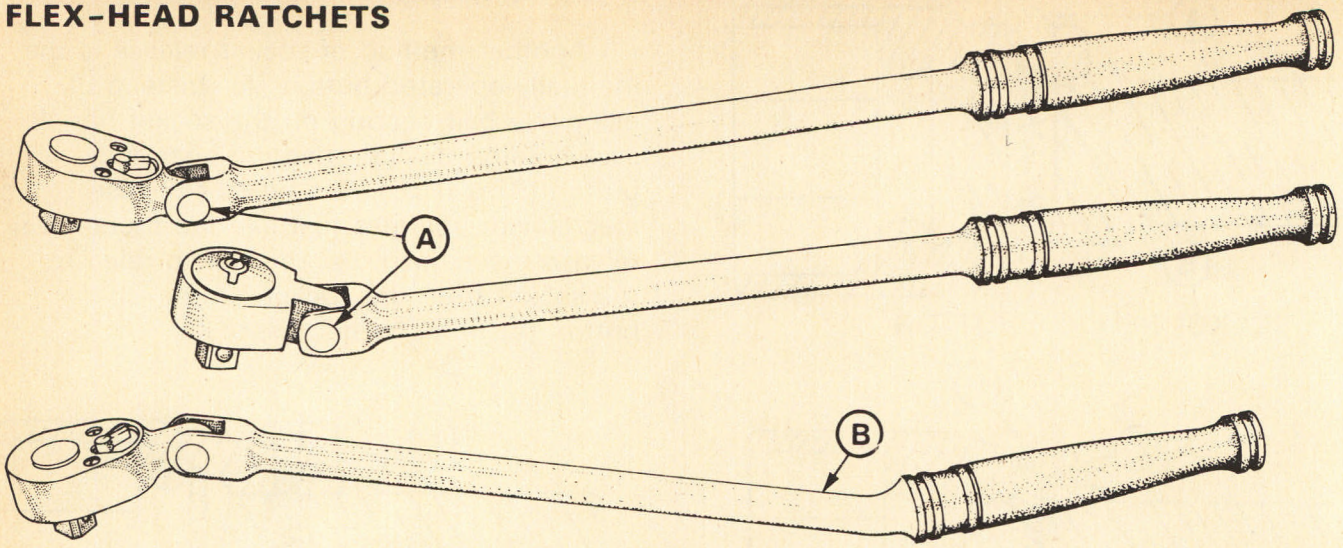
HEAVY-DUTY RATCHETS



The heavy-duty ratchet is designed for rugged use; the body (B) is thickly constructed (compared to the standard ratchets first shown in this section) and usually comes with interchangeable handles (C) to allow the use of longer handles for more torque leverage. The heavy-duty ratchet usually comes with ¾-inch up to 2-inch square drives (A).

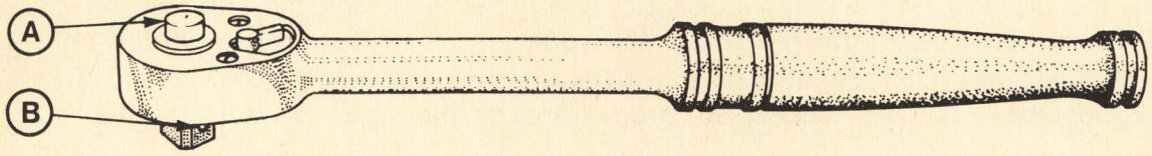
SOCKET HANDLES

FLEX-HEAD RATCHETS



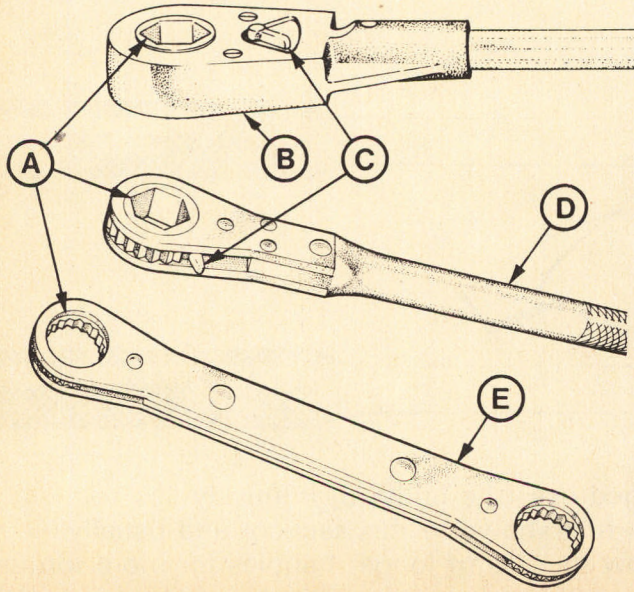
The flex-head ratchets shown here operate the same as the standard ratchets. Only the head design is different, depending on the type of job for which you need it. These ratchets save you time on jobs that are close to obstructions (great for spark plug work). The flex head (A) has a spring built into the head to hold it at any desired angle for placement on the job to be done. Some flex head ratchets even come with bent handles (B) to allow a greater degree of clearance around obstructions.

FAST-RELEASE RATCHET



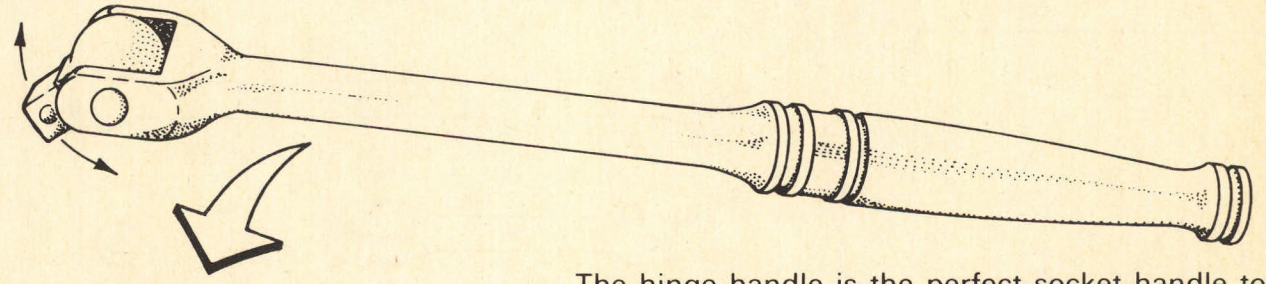
To release your socket with greater ease, just depress the button (A) and your socket will drop off. By depressing the button, you override the spring pressure behind the ball bearing (B), allowing the weight of the socket to slip over the ball bearing (great if your hands are greasy).

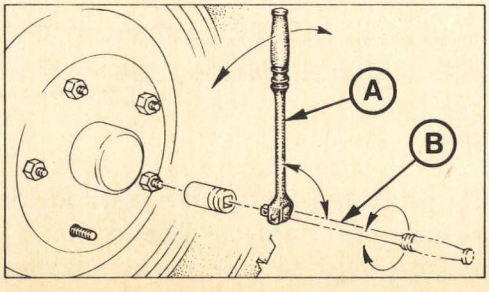
RATCHETING SOCKETS



The ratcheting sockets have no square drive or need for a socket because they have an internal socket (A) built in. When working space is very limited and obstructions or long, protruding bolts prevent use of the standard socket and ratchet, you will find the ratcheting socket a must. It is very flat and is available with shorter or longer interchangeable handles. The ratcheting socket (B) is the same as ratcheting sockets (D) and (E) except for the type of selector (C) used for changing the direction of rotation of internal socket (A).

HINGE HANDLE (OR BREAKER BAR)

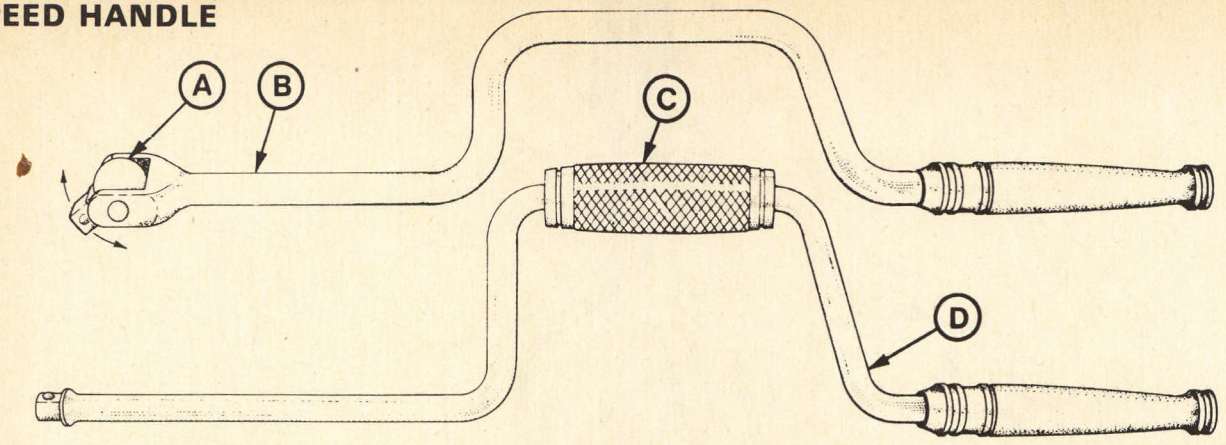




The hinge handle is the perfect socket handle to break loose those stubborn bolts and nuts. It comes with many different handle lengths for greater leverage and can be used in almost any position. The nut or bolt can be broken loose using the handle in the vertical position (A). Then by lowering the handle to the horizontal position (B), the nut or bolt can be twisted out rapidly between the fingers in the same manner as a screwdriver.

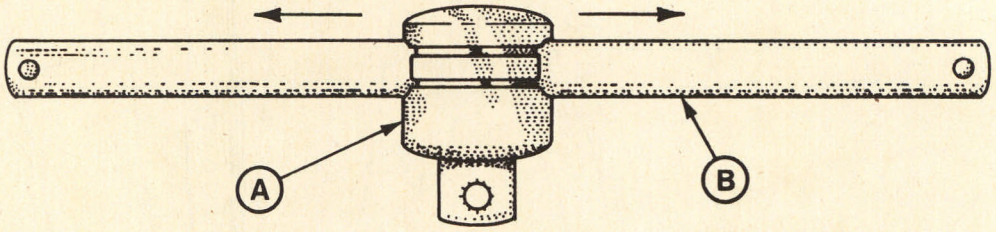
SOCKET HANDLES

SPEED HANDLE



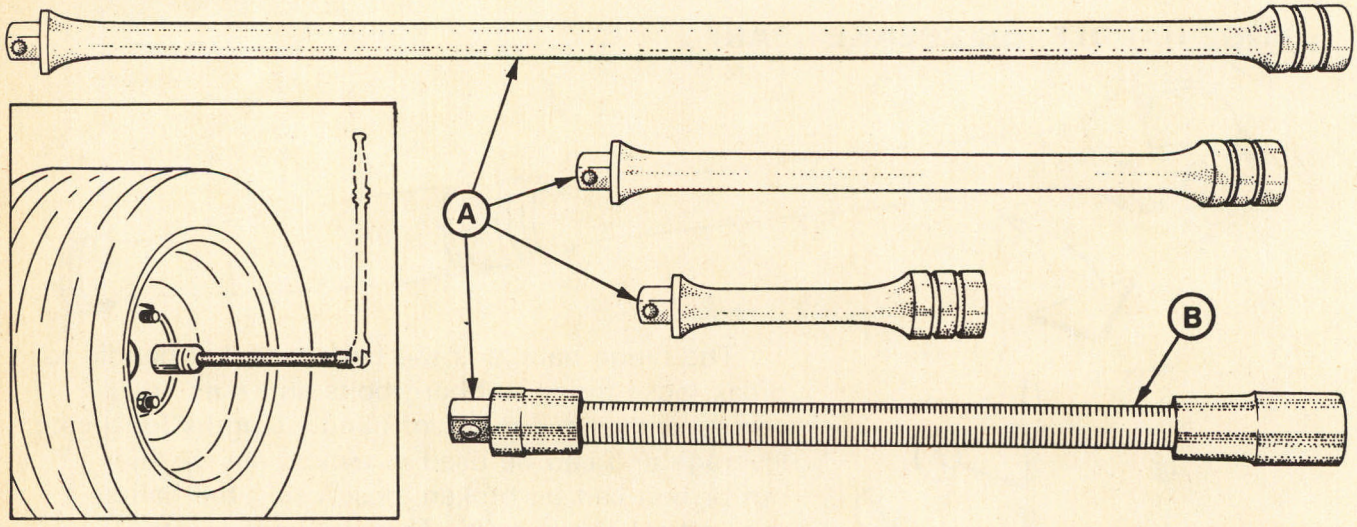
Speed handles are just what their name indicates, handles for speeding up the removal or insertion of any fastener that's well exposed. The differences in the two handles shown are simple. Handle (B) has a hinged square drive (A), which makes this a dual-purpose speed handle by allowing you to remove or install fasteners from almost any position. Handle (D) has a knurled (a series of ridges cut into the handle for better gripping power) swivel handle (C) to aid in faster turning of nuts and bolts.

SLIDING T-HANDLE



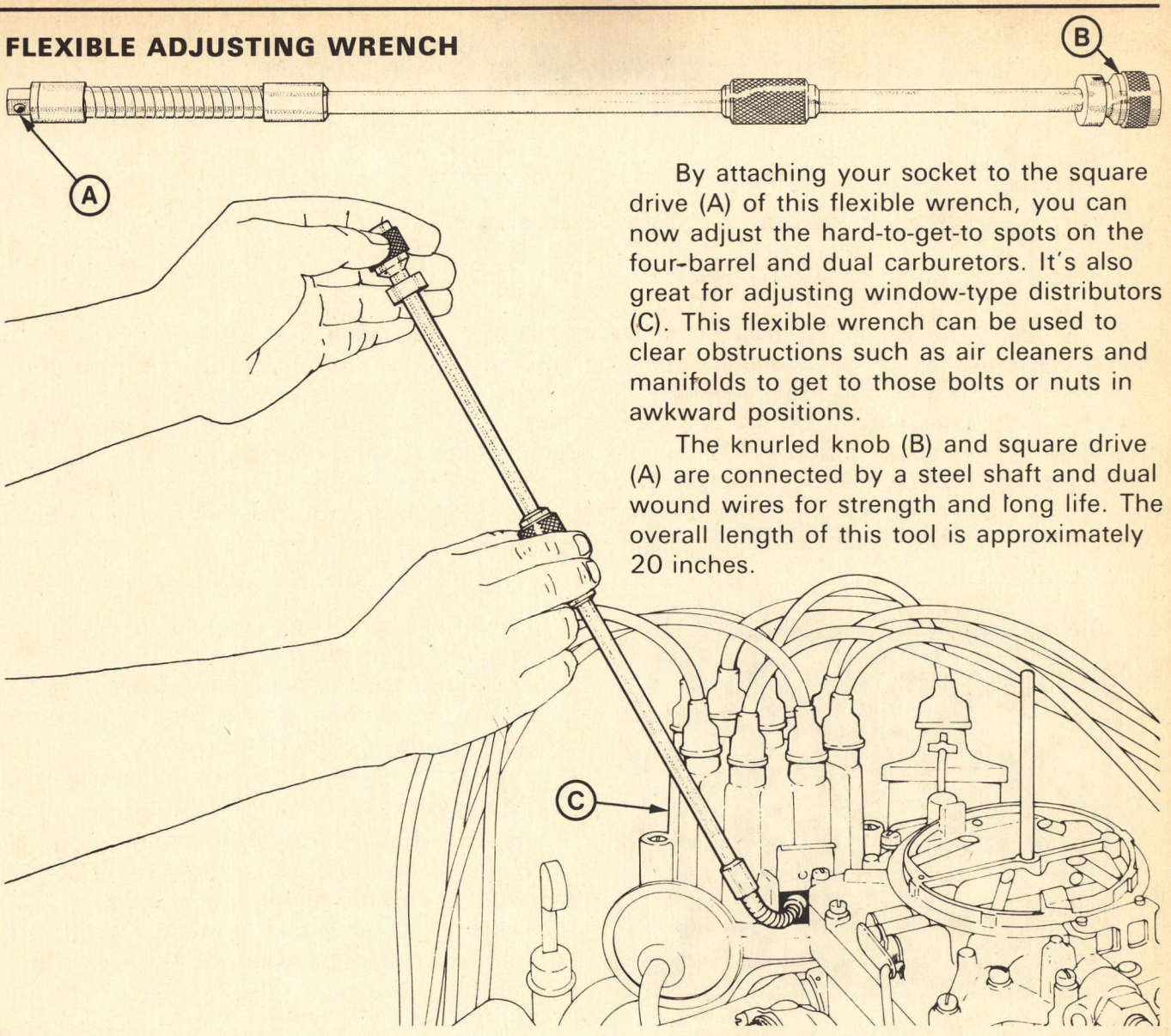
The sliding T-handle has a ball bearing (or friction ball) built into the movable square drive head (A). As the head is centered on the bar (B), the friction ball drops into a groove cut around the center of the bar to make a practical T-handle. The movable head can travel either direction on the bar to be used as an offset handle as well.

EXTENSION BARS



Extension bars come in many varied lengths. To get the job done faster, it's a good idea to have most available lengths on hand. Extension bars are used primarily to get to those hard-to-reach areas. Naturally, they come in all sizes of square drives (A). Some extensions are not solid but are made with a strong spring (B) for flexibility.

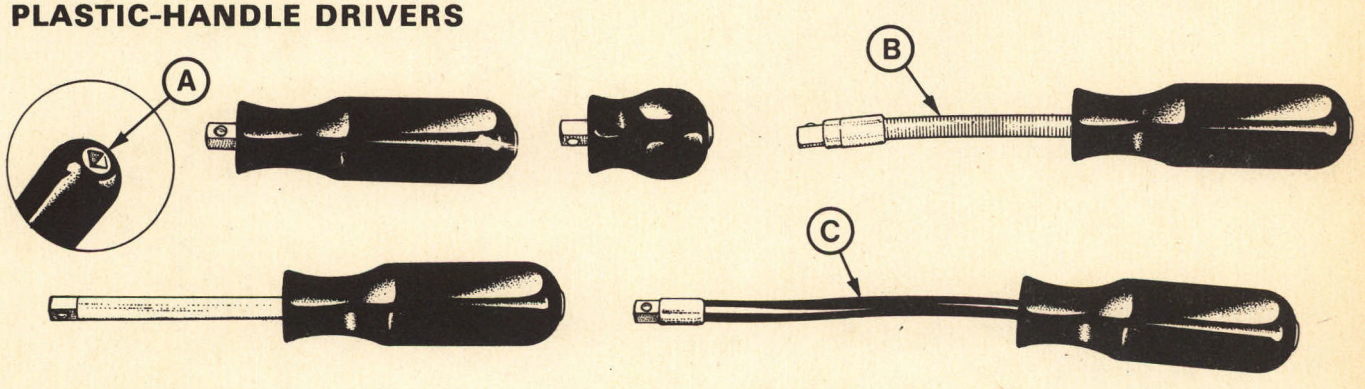
FLEXIBLE ADJUSTING WRENCH



By attaching your socket to the square drive (A) of this flexible wrench, you can now adjust the hard-to-get-to spots on the four-barrel and dual carburetors. It's also great for adjusting window-type distributors (C). This flexible wrench can be used to clear obstructions such as air cleaners and manifolds to get to those bolts or nuts in awkward positions.

The knurled knob (B) and square drive (A) are connected by a steel shaft and dual wound wires for strength and long life. The overall length of this tool is approximately 20 inches.

PLASTIC-HANDLE DRIVERS

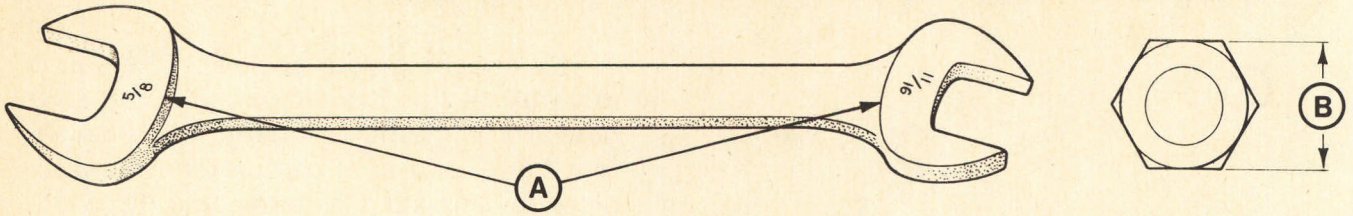


As you can see, there are many different lengths of plastic-handle drivers, all for specific needs. Some drivers have a female square drive (A) built into the plastic handles so that an extension bar or other socket handle can be snapped on for additional leverage.

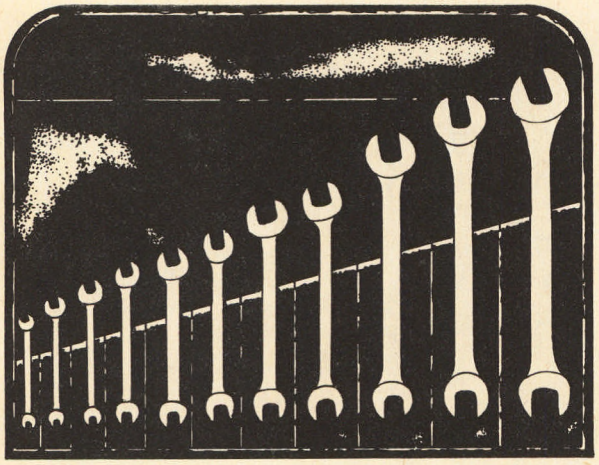
Two other types of plastic-handle drivers are the flexible-shaft driver (B) for those hard-to-reach spots and the flexible insulated-shaft driver (C) to prevent accidental shorting out on the coil when adjusting points or other electrical components.

As you can see, there are many, many kinds of socket handles produced today. Know your needs and shop around for the best quality tool to fill your tool box.

OPEN-END WRENCHES

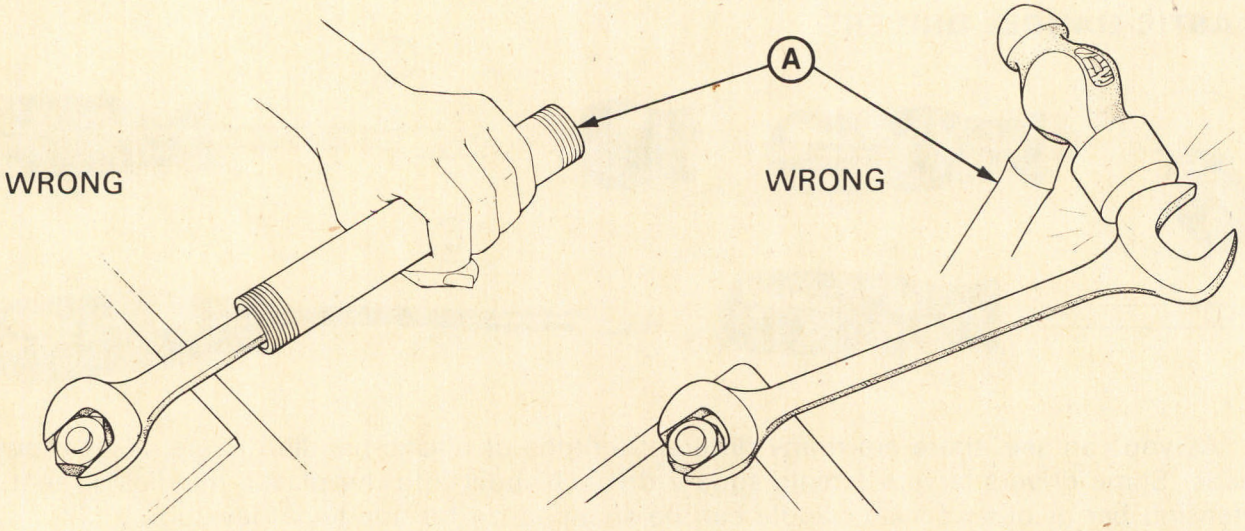


The open-end wrench is one of the most commonly used wrenches in the tool box. It is solid, non-adjustable and is usually made of Chrome Steel for strength. The size (A) of the wrench is usually stamped in the wrench on or near the corresponding head. For example, a wrench with a 5/8-inch opening on one end and an 11/16-inch opening at the other end would be referred to as a 5/8 x 11/16-inch wrench. Actually, the opening in the head of the wrench is .005-inch to 0.15-inch larger than the size marked on the wrench so it will slip over the nut or bolt easily. The size of the wrench does not mean the bolt diameter, but actually refers to the distance (B) across the flats of the nut or bolthead.

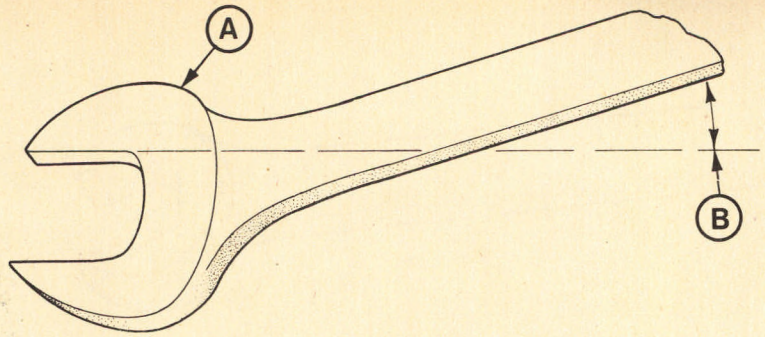


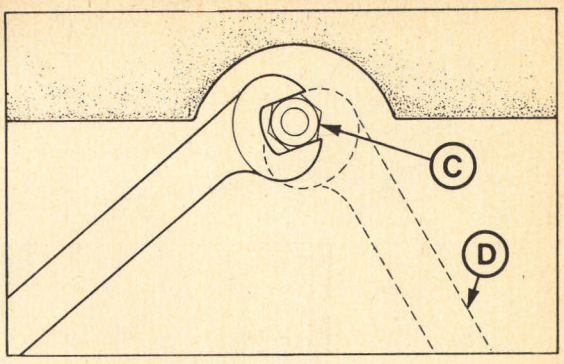
Open-end wrenches are sold individually or in sets and are also available in metric sizes. An average set of wrenches for automotive and general work usually contains 10 to 12 wrenches ranging in size from 5/16-inch to 1 inch.

Wrenches with smaller openings are shorter in length than wrenches with larger openings. The ratio between the length of the wrench and the opening is purposely built into the wrench by the manufacturer so the proper amount of torque is exerted on the nut or bolthead.

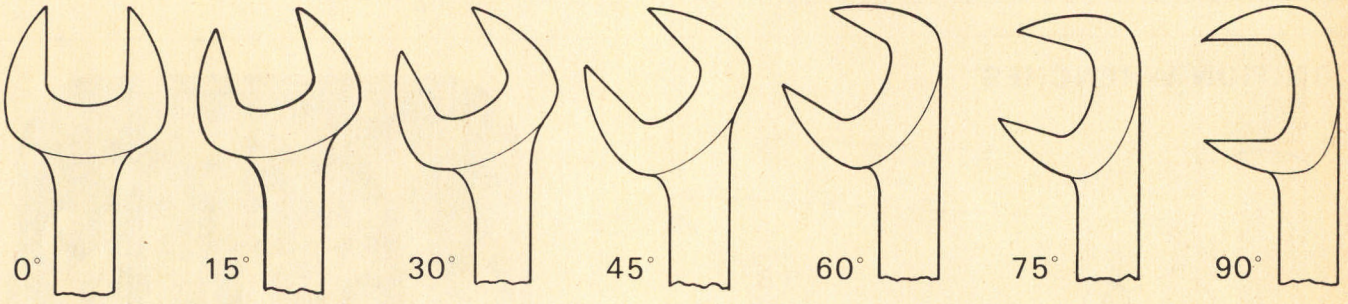


Because the proper leverage (length) for the wrench is "built in" by the manufacturer, it is a very poor practice to apply additional leverage (A) to the wrench. This additional leverage can result in cracked or broken wrenches, rounded corners on nuts or boltheads and broken or stretched nuts, bolts or studs.

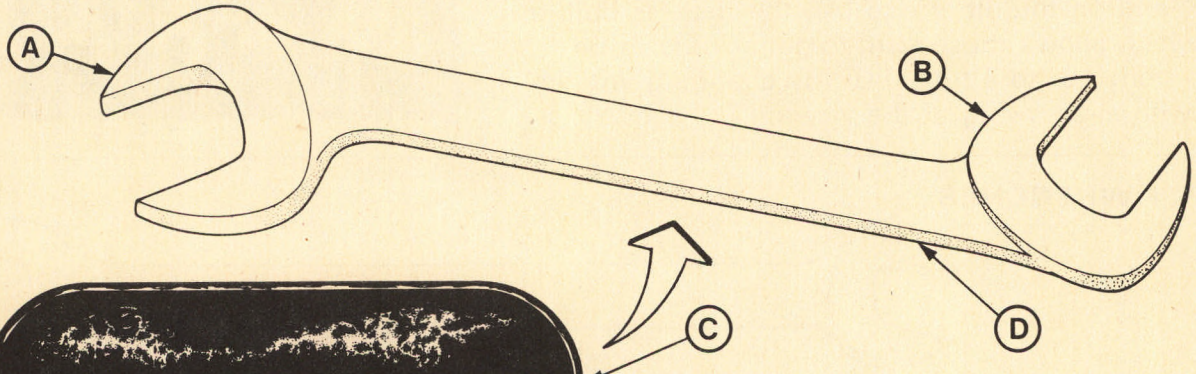


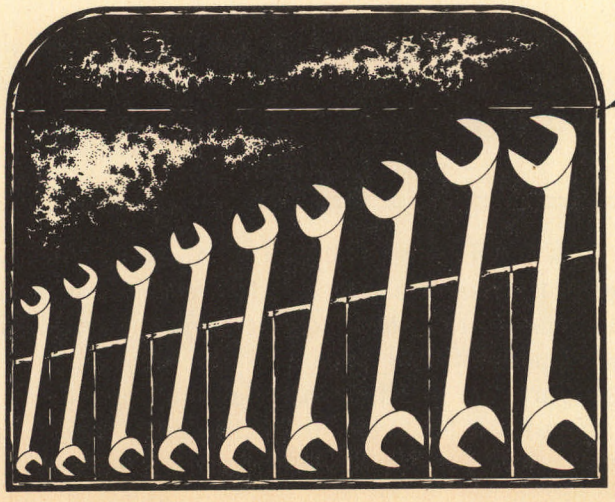


The standard open-end wrench is built with the head (A) placed at a 15° angle (B) to the handle. This angle makes it possible for the wrench to turn a nut or bolt (C) in tight spaces where little space is available to swing the wrench. By turning the wrench over (D) after each swing, the angle of the opening becomes reversed, thus making it possible to turn a hexagonal (six-sided) nut or bolthead through a 30° arc.



It is possible to purchase wrenches with straight heads (no angle), but as you can see, they become almost useless in tight spaces. On the other hand, some open-end wrenches may be purchased with the head angle as high as 90°.

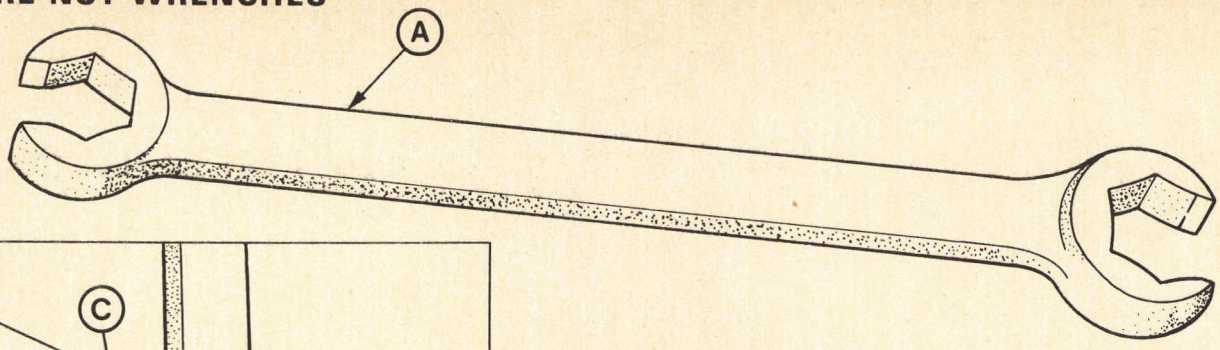


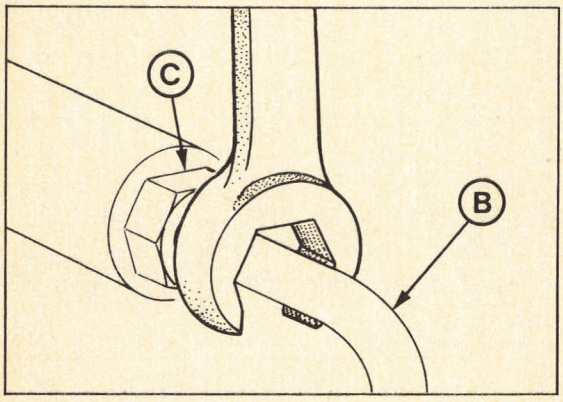


A wise investment would be to purchase a set of double-angled open-end wrenches (C). These wrench ends have the same size opening, but each end is set at a different angle. By merely changing ends of the wrench, four different positions can be obtained. The wrench (D), for example, has a 1-inch opening on each end. End (A) is set at 30° and end (B) at 60°. Changing wrench ends allows a full 180° swing in those tight spaces.

OPEN-END WRENCHES

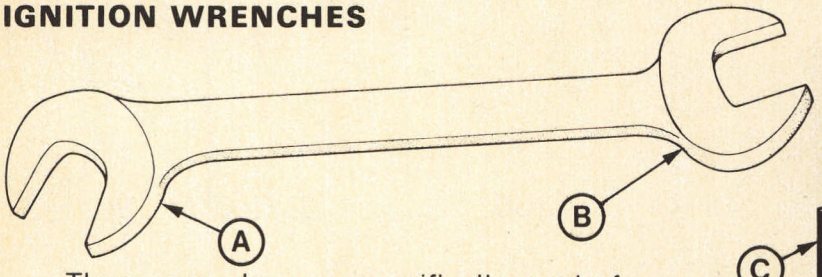
FLARE-NUT WRENCHES

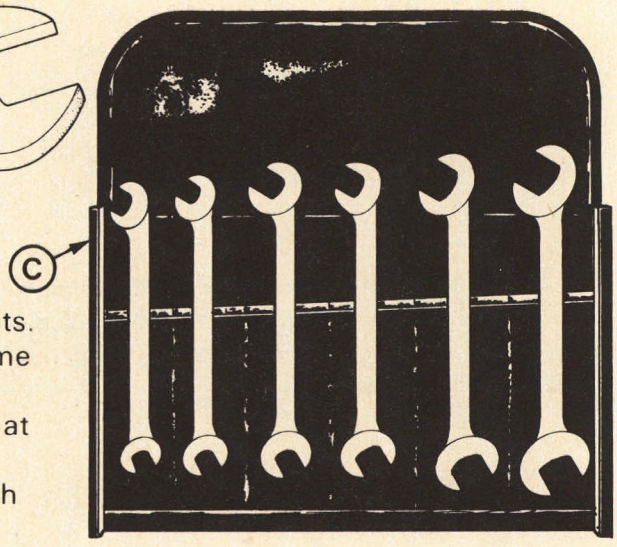




The purpose of the flare-nut wrench (A) is to remove automotive soft metal flare nuts (C). The shape of the head insures an excellent fit on the nut (about 270° around) thereby preventing rounding or distortion of the soft metal flare nut corners. The wrench is first placed on the line (B) and then moved to the nut, where it is slipped on for either tightening or loosening.

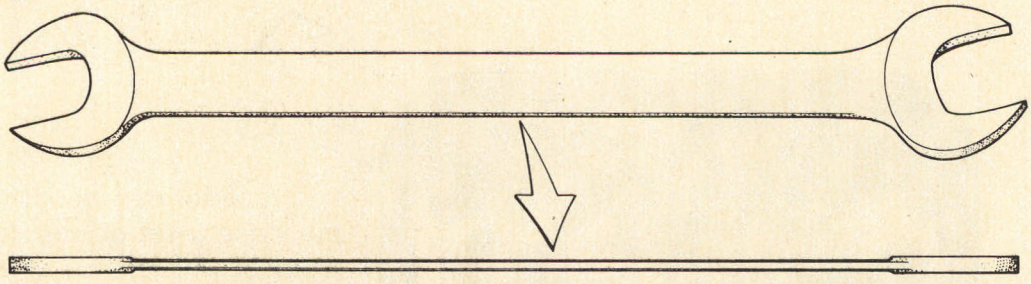
IGNITION WRENCHES





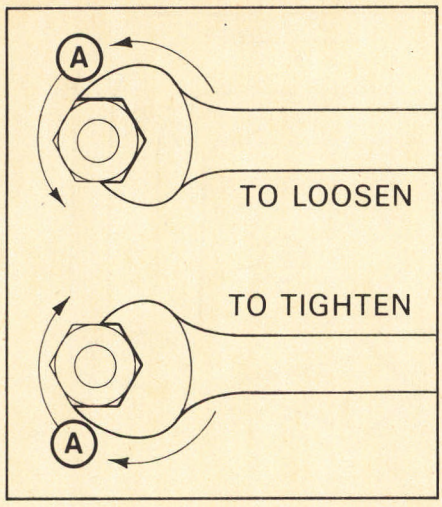
These wrenches are specifically made for working on small, hard-to-get-at ignition components. They are very thin, short wrenches and usually come in sets (C) of six. On one end (B), the head is built at 30°, and on the other end (A), the head is built at 60°, which allows those hard-to-get-at nuts to be turned from 15° to a full 180° (by changing wrench ends) with each swing of the wrench.

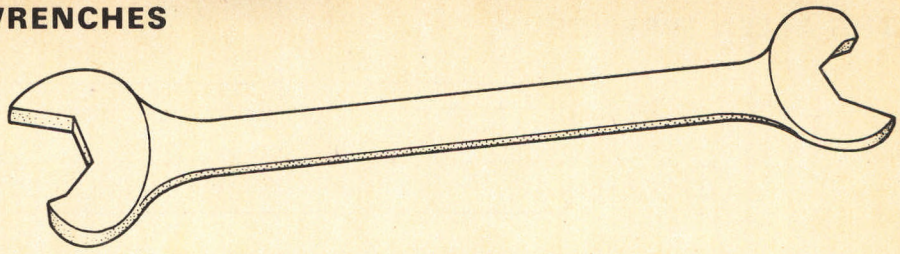
TAPPET WRENCHES



Tappet wrenches are made for the purpose of adjusting the tappets (sometimes a very hard-to-get-at engine part) on automotive engines. The handles and heads are extremely long and thin to prevent the mechanic from getting his hands too close to hot engine parts while adjusting the tappets. These wrenches are usually made of tool steel and are very thin to allow entrance into cramped quarters. (Tool steel is a term used in the machine-building industry. It is any steel that is suitable for making cutting tools or other classes of tools. Tool steel contains sufficient amounts of carbon so that it will harden if heated above a certain temperature and then cooled rapidly.)

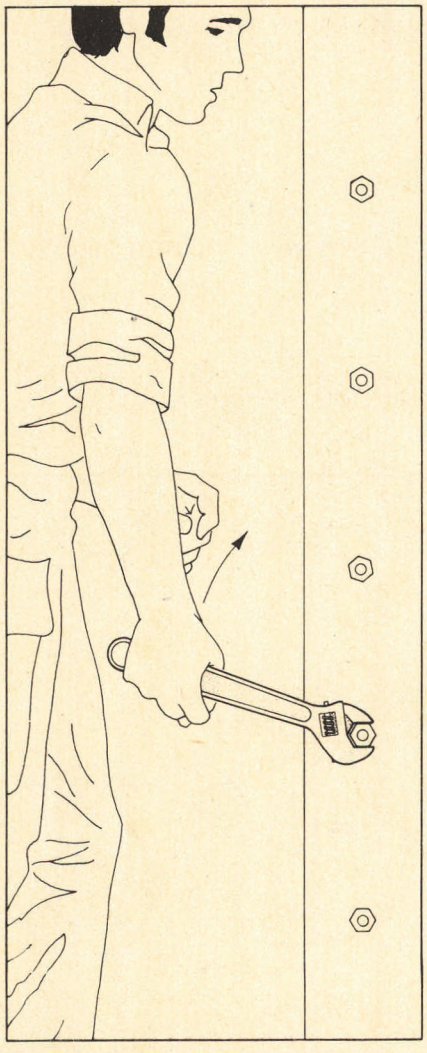
RATCHETING OPEN-END WRENCHES

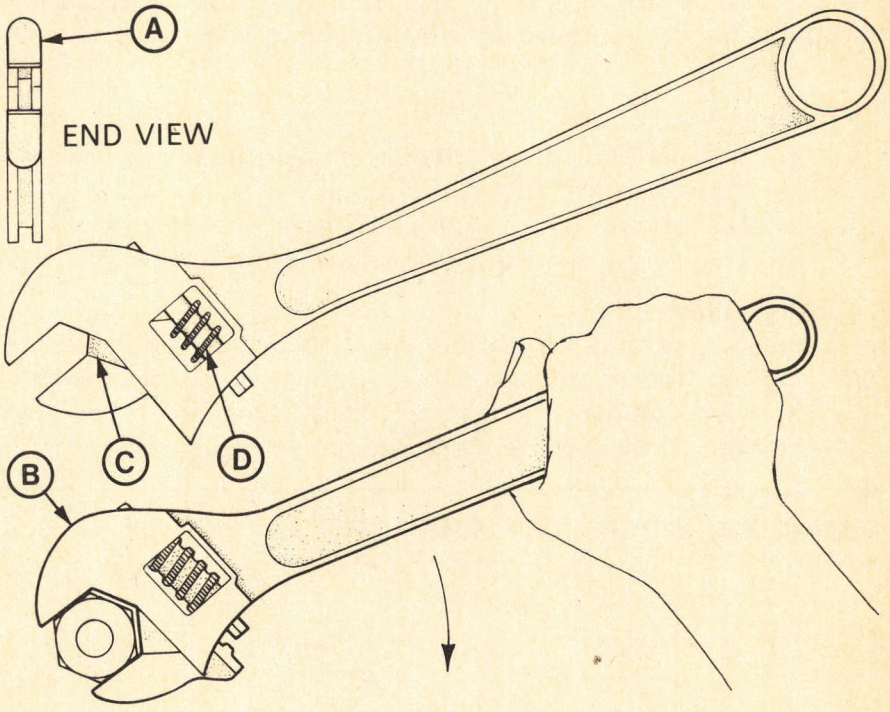




The ratcheting open-end wrench is designed to allow ratcheting speed with the convenience of an open-end wrench. It must be used very carefully, because there is not enough jaw area to allow a very secure grip on the nut or bolthead. Do not use this wrench to break loose or to complete the tightening sequence of a nut or bolt. Always turn the nut or bolt in direction (A). (Notice the position of the "short" jaw.) This will prevent slippage and rounding off of the nut and bolthead corners.

ADJUSTABLE OR CRESCENT WRENCH





Adjustable wrenches come in handy at times but should never be used as a substitute for an open-end or box-end wrench. Use caution when pulling hard on an adjustable wrench. It is a good idea to inspect these wrenches occasionally for:

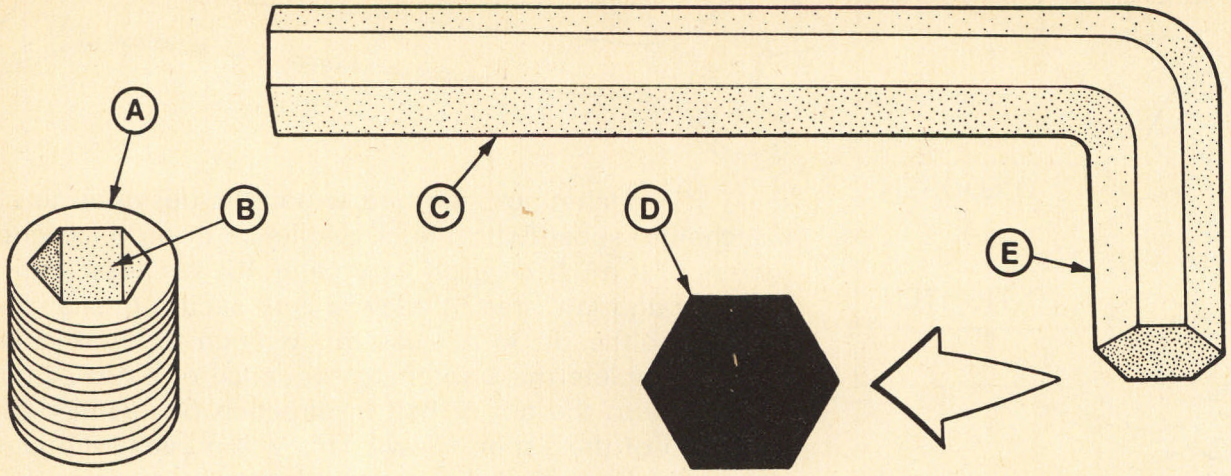
1. Cracks in web area (C).
2. Jaws remaining parallel (A).
3. Proper operation of the knurled nut (D).

Adjustable wrenches can be pulled in either direction for light loads but develop their greatest strength when pressure is applied to the side of the wrench with the fixed jaw (B).

Always be sure the wrench is adjusted (by turning the knurled nut [D]) as tight as possible against the nut or bolthead) before attempting to tighten or loosen any nut or bolt.

OPEN-END WRENCHES

THE ALLEN WRENCH



The Allen wrench is the most popular of the headless setscrew wrenches. It is an L-shaped bar of hardened steel with a hexagonal (six-sided) section (D). It is made to fit the hexagonal hole (B) in Allen cap or setscrews (A). These screws are used on pulleys, collars and other moving parts or on any revolving shaft where a protruding screw will not work well.

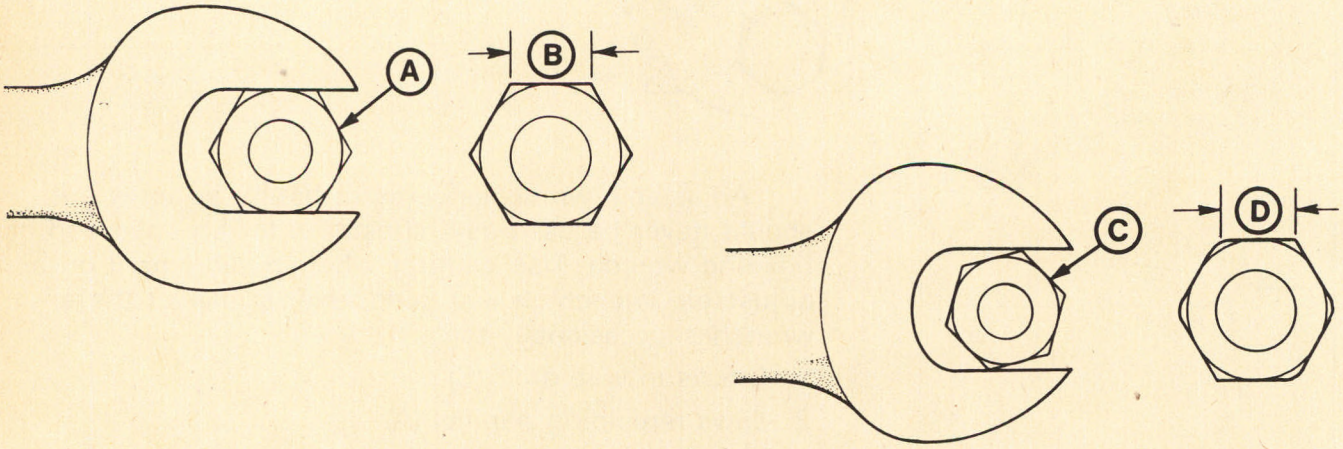
To remove Allen screw:

1. Place short end (E) of Allen wrench in hole of screw (A).
2. Loosen screw (A). Remove wrench.
3. Insert long end (C) of wrench in hole of screw (A).
4. Remove screw by turning wrench counterclockwise. Remove Allen wrench from screw.

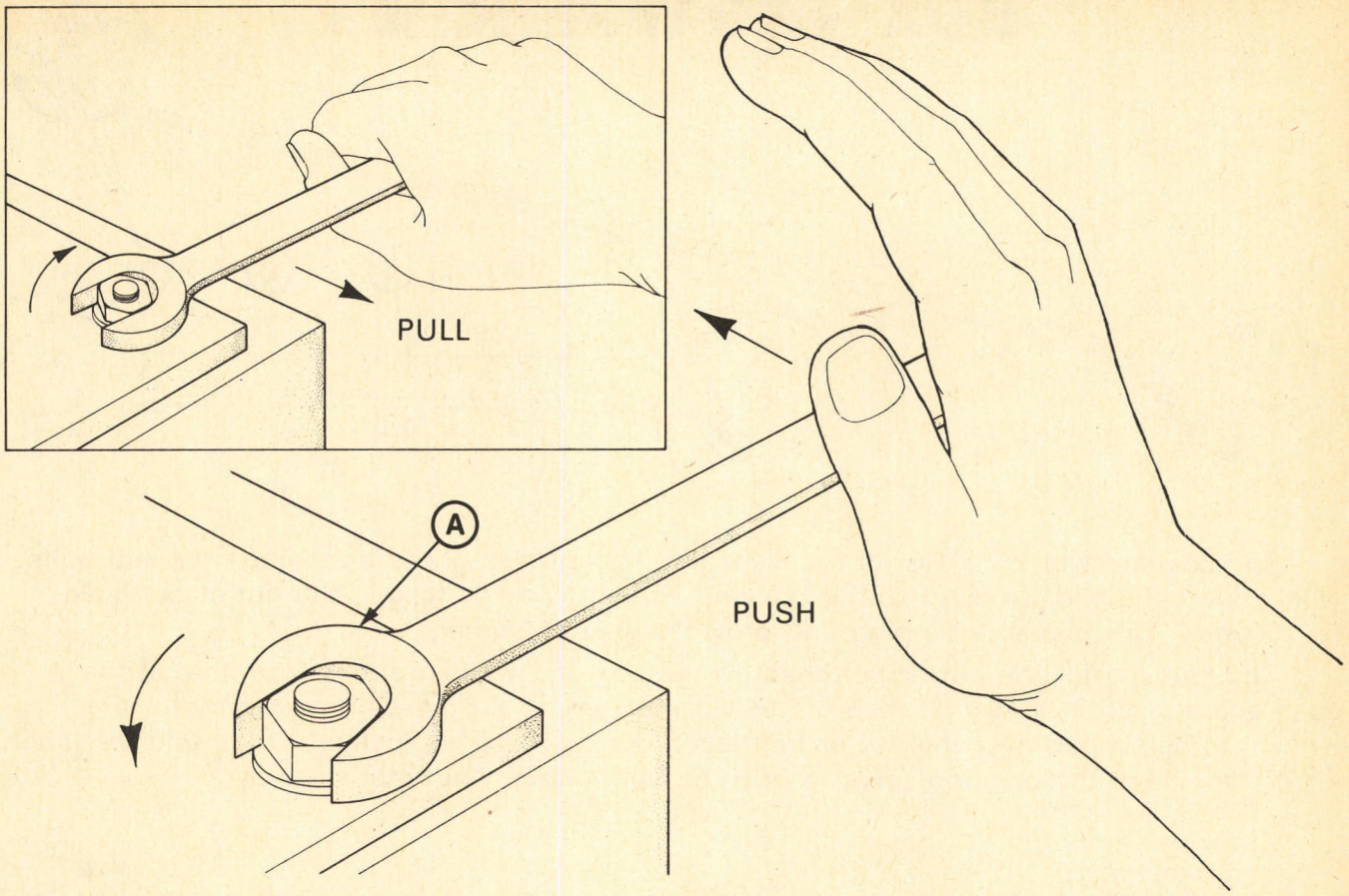
To install Allen screw:

1. Insert long end (C) of Allen wrench in hole of screw (A).
2. Tighten screw until snug by turning wrench clockwise.
3. Remove wrench from screw. Insert short end (E) of wrench in hole of screw (A).
4. Tighten screw (A). Remove wrench from screw.

USING THE OPEN-END WRENCH



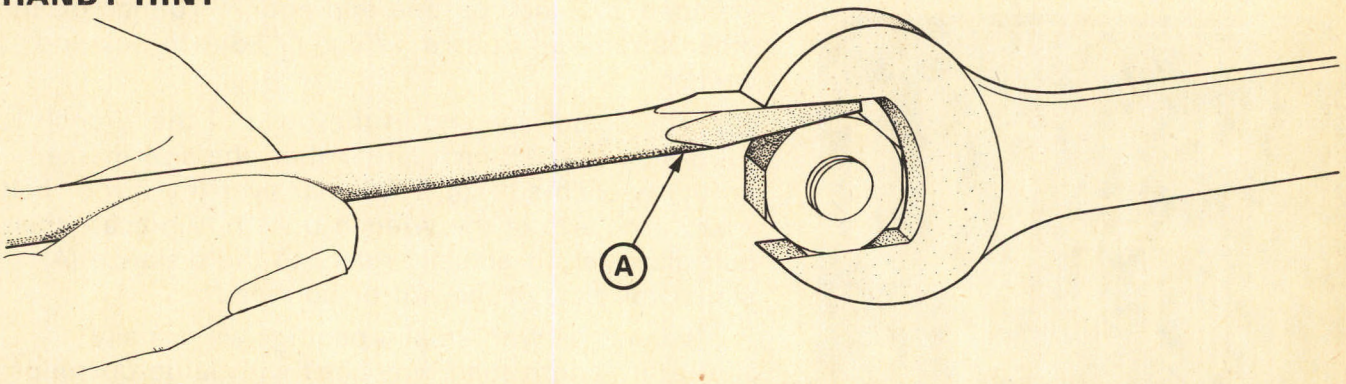
The importance of using the proper size wrench for the nut or bolthead you wish to turn cannot be overemphasized. If the correct size wrench is used, the fit (A) is snug and secure, with the result that the nut or bolthead retains its sharp corners (B). If too large a wrench is used, the loose fit (C) results in a nut or bolthead with rounded corners. This makes the nut or bolthead harder to turn the next time, due to damaged corners (D).



Open-end wrenches always perform best when placed squarely on the nut or bolthead and pulled toward you. To exert less strain on the nut or bolthead, always place the wrench on the nut or bolt with the long portion (A) moving in the direction of the force being applied. By pulling instead of pushing on the wrench, you can usually avoid hurting your hand if the wrench should slip. If it becomes necessary to push the wrench, always push with the palm of the hand, making sure the fingers are spread open to avoid skinned knuckles if the wrench slips.

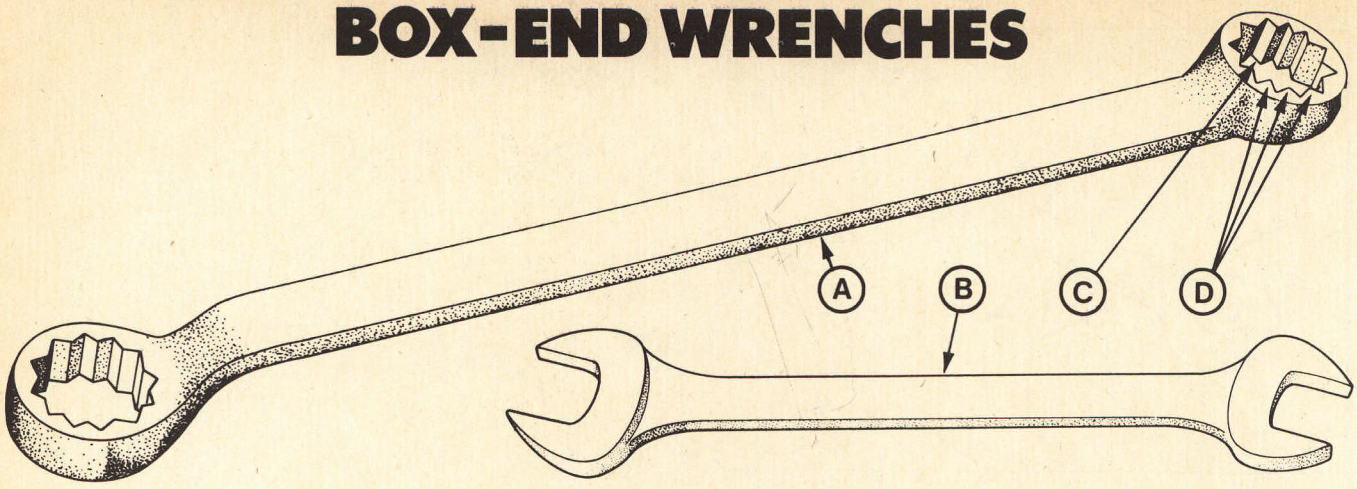
Be sure your hands are dry and the wrench is clean and dry before attempting to loosen a stubborn nut or bolt. Using a greasy wrench increases the chances of slippage and possible skinned knuckles. Also, be sure your footing is good.

HANDY HINT



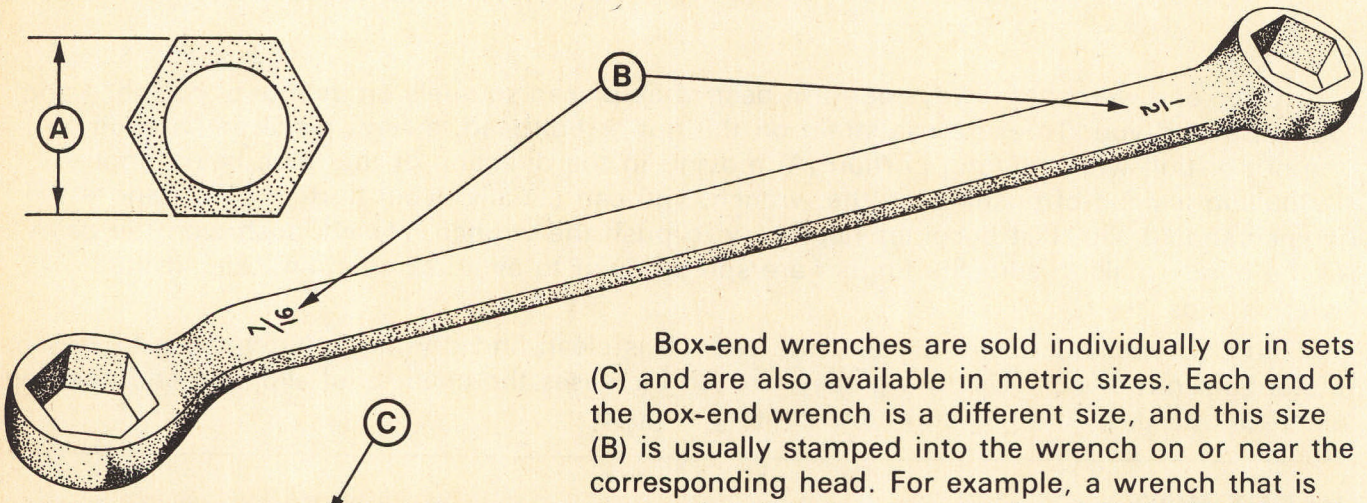
If the corners of the nut to be removed are rounded off and the wrench does not fit snugly on the nut, it can still be removed by placing the wrench on the nut in the normal manner and then wedging a screwdriver (A) between the nut flat and the jaw of the wrench. This will take up the slack space between the wrench jaw and nut flat and allow you to remove the nut in the normal manner.

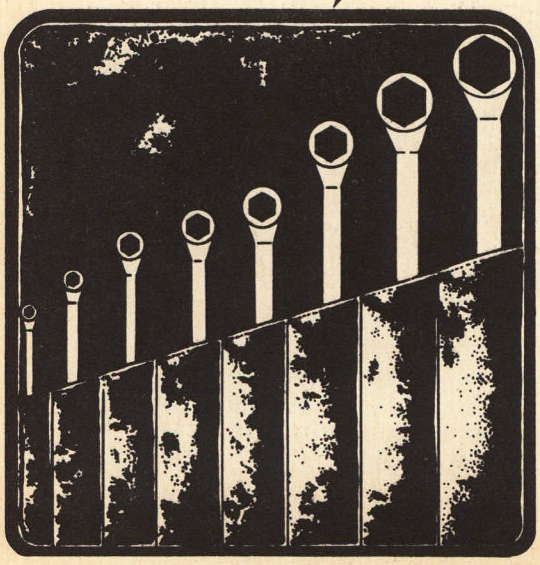
BOX-END WRENCHES



The box-end wrench (A) is an excellent tool for tightening and loosening nuts and bolts. Unlike the open-end wrench (B), the box-end wrench is made to grip the nut or bolthead on all sides. This prevents slipping and provides greater leverage.

The opening for the nut or bolthead on the box-end wrench differs from that of the open-end wrench in that it is closed. This closed opening (C) makes it necessary for the wrench to be slipped over the nut or bolthead. The sharp edges (points) (D) around the inner circumference of the opening serve to grip the bolthead or nut more securely.

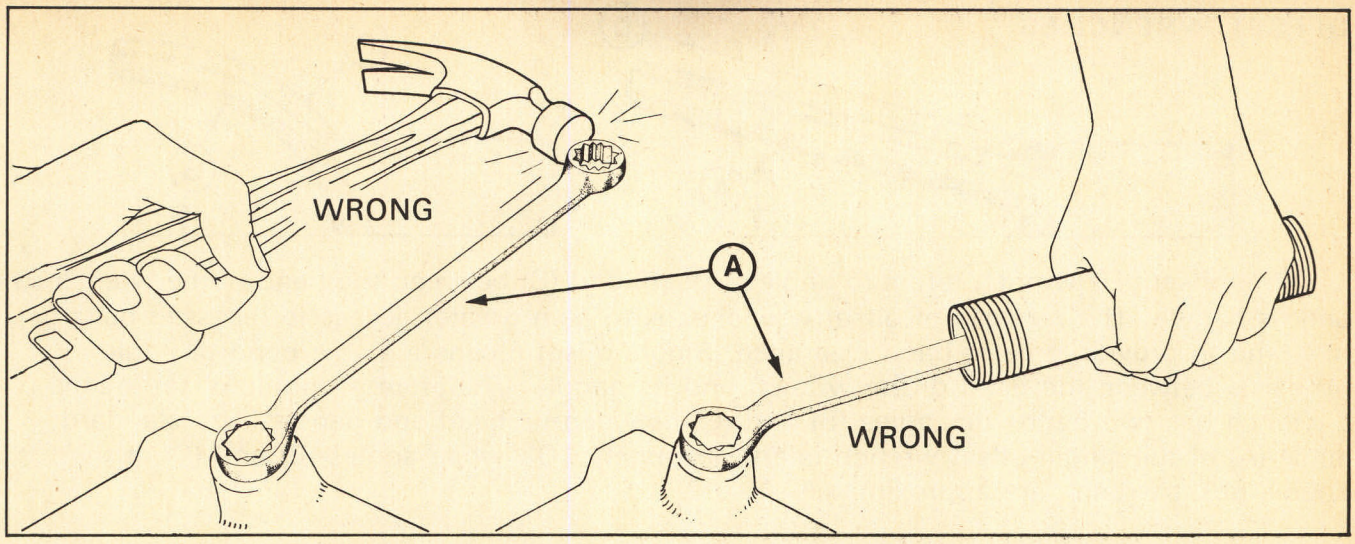




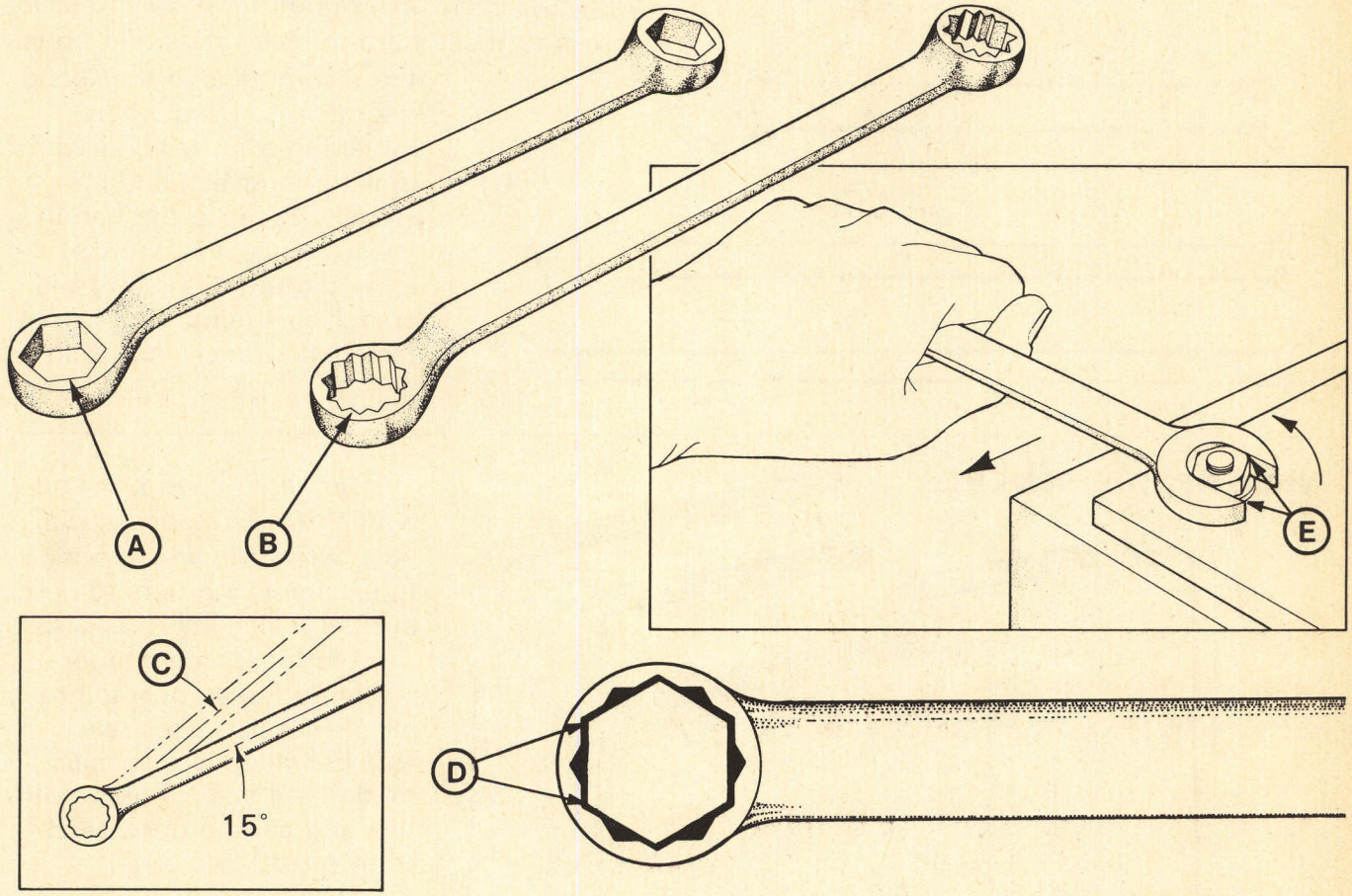
Box-end wrenches are sold individually or in sets (C) and are also available in metric sizes. Each end of the box-end wrench is a different size, and this size (B) is usually stamped into the wrench on or near the corresponding head. For example, a wrench that is stamped 1/2-inch on one end and 7/16-inch on the other is referred to as a 1/2 x 7/16-inch box-end wrench.

The actual opening in the head of the wrench is .005-inch to 0.15-inch larger than the size marked on the wrench so that it will slip over the nut or bolt easily. The size of the wrench does not indicate the bolt diameter; it actually refers to the distance (A) across the flats of the nut or bolthead.

Wrenches with small openings are usually shorter in length than wrenches with large openings. The exceptions to this rule will be discussed later on. The ratio between the length of the wrench and the opening is purposely built into the wrench so that the proper amount of torque will be exerted on the nut or bolthead.



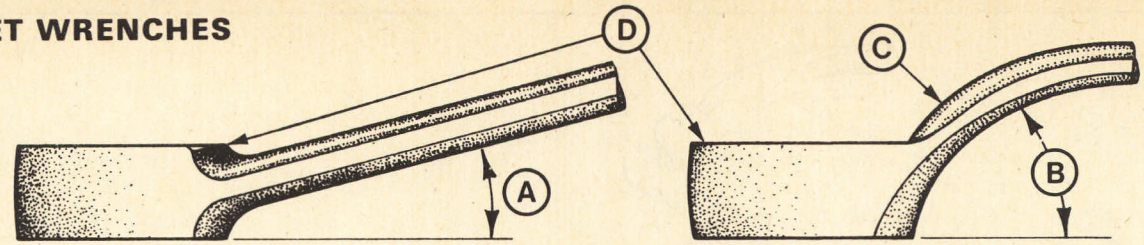
Because the proper leverage length of the wrench is ''built in'' by the manufacturer, it is a very poor practice to apply additional leverage (A) to the wrench. This additional leverage can result in cracked or broken wrenches, rounded corners on nuts or boltheads and broken or stretched nuts, bolts or studs.



The box-end wrench is designed with either a six-point (A) or 12-point (B) opening on each end. The 12-point opening is good for general use and for work in tight spaces. The 12 points allow the nut or bolt to be turned through an arc of only 15° (C) or half a turn before it is necessary to reposition the wrench for another swing. The 12 points of the box-end wrench exert pressure on the six points (D) of a nut or bolthead instead of on just two points (E) as with the open-end wrench. For stubborn jobs or on damaged nuts or boltheads, the six-point wrench does a better job. The six-point wrench grips the nut or bolthead across each flat, thereby reducing slippage to a minimum.

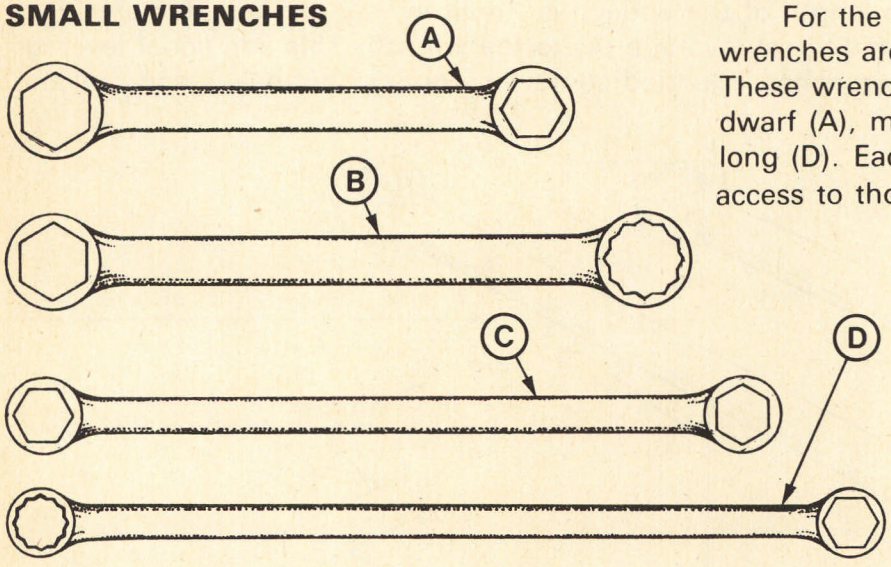
BOX-END WRENCHES

OFFSET WRENCHES



The offset of a wrench refers to angles (A), (B) and (C) between the head of the wrench (D) and its handle. The purpose of offset wrenches is to gain greater access to recessed bolts or nuts and to provide greater hand clearance. Single offset means a single bend or angle (A) exists between the head of the wrench and its handle. Therefore a double offset means a wrench has two bends or angles (B) and (C) between its head and handle. The standard angle (A) of the single-offset wrench is approximately 10°, while angles (B) and (C) of the double-offset wrench are approximately 45°.

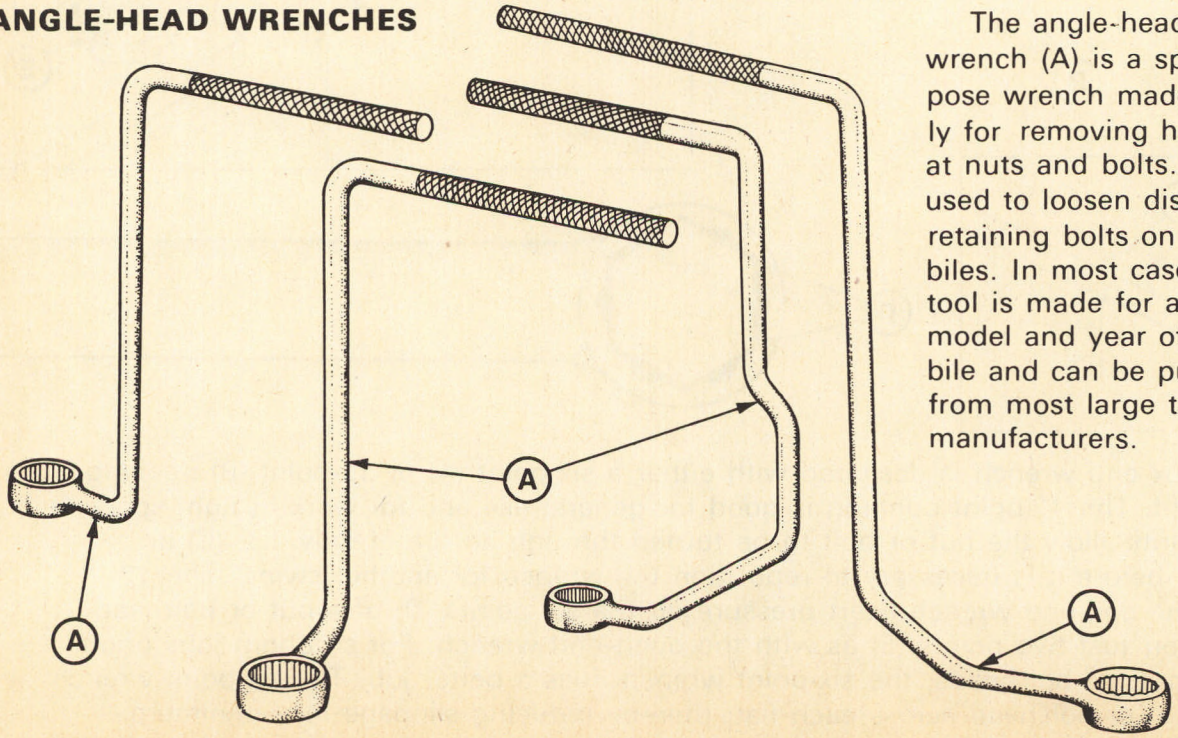
SMALL WRENCHES



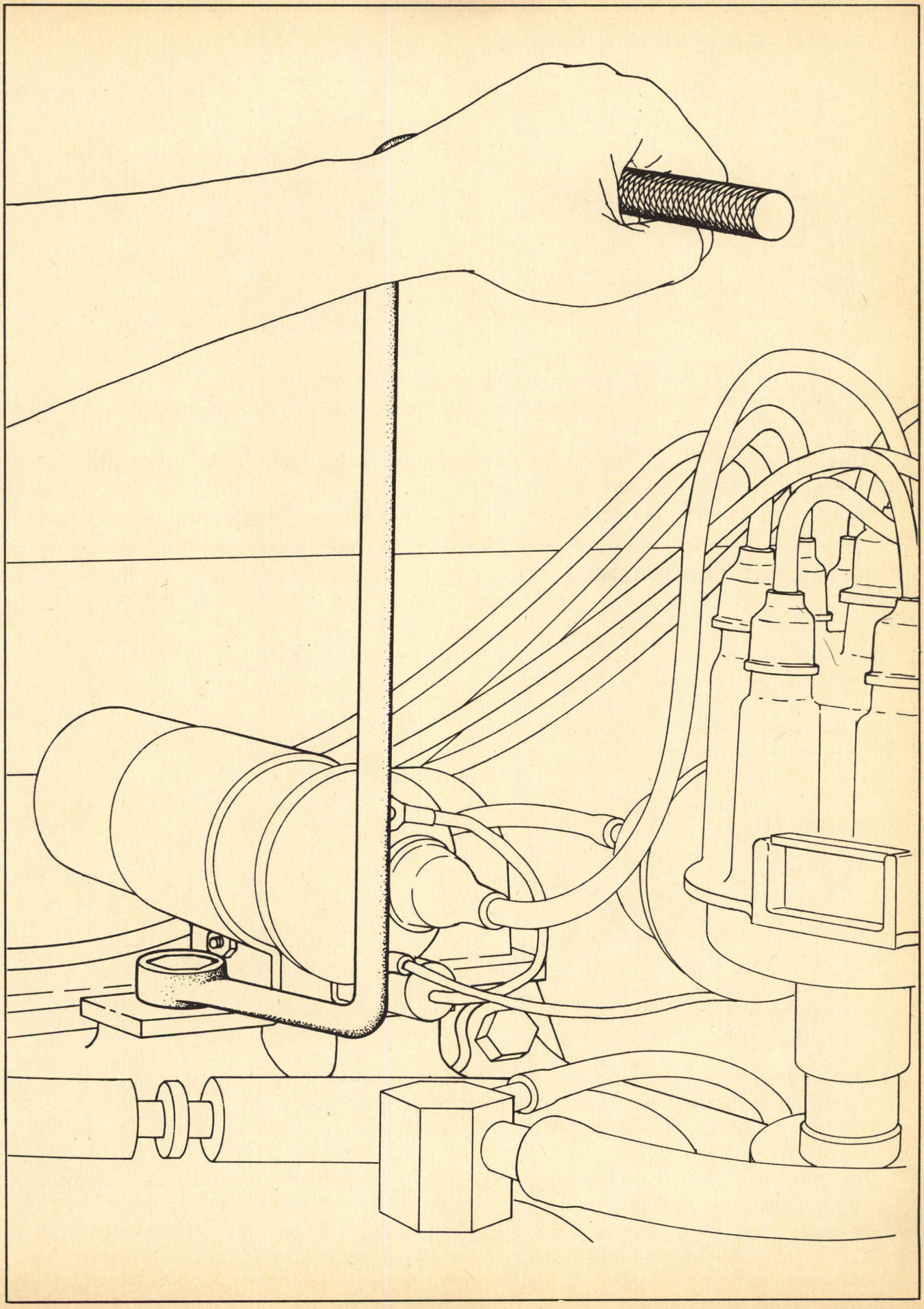
For the sake of convenience, box-end wrenches are available in different lengths. These wrench lengths are referred to as dwarf (A), midget (B), standard (C) and extra long (D). Each is designed to allow the user access to those hard-to-reach nuts and bolts.

It is recommended that good judgment be used when tightening a nut or bolt with an extra-long box-end wrench. Because the handle is extra long, it is easy to apply too much force to the wrench, resulting in a damaged wrench, nut, bolt or stud.

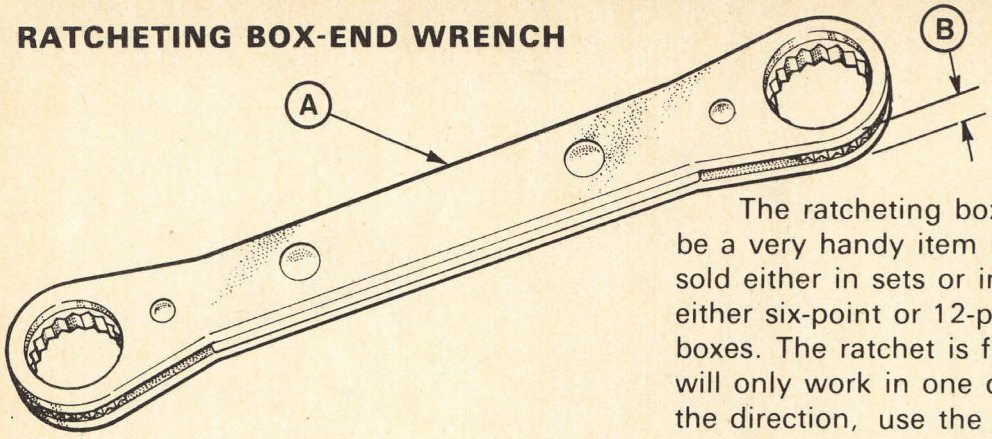
ANGLE-HEAD WRENCHES



The angle-head box-end wrench (A) is a special-purpose wrench made specifically for removing hard-to-get-at nuts and bolts. It is also used to loosen distributor retaining bolts on automobiles. In most cases, each tool is made for a specific model and year of automobile and can be purchased from most large tool manufacturers.



RATCHETING BOX-END WRENCH

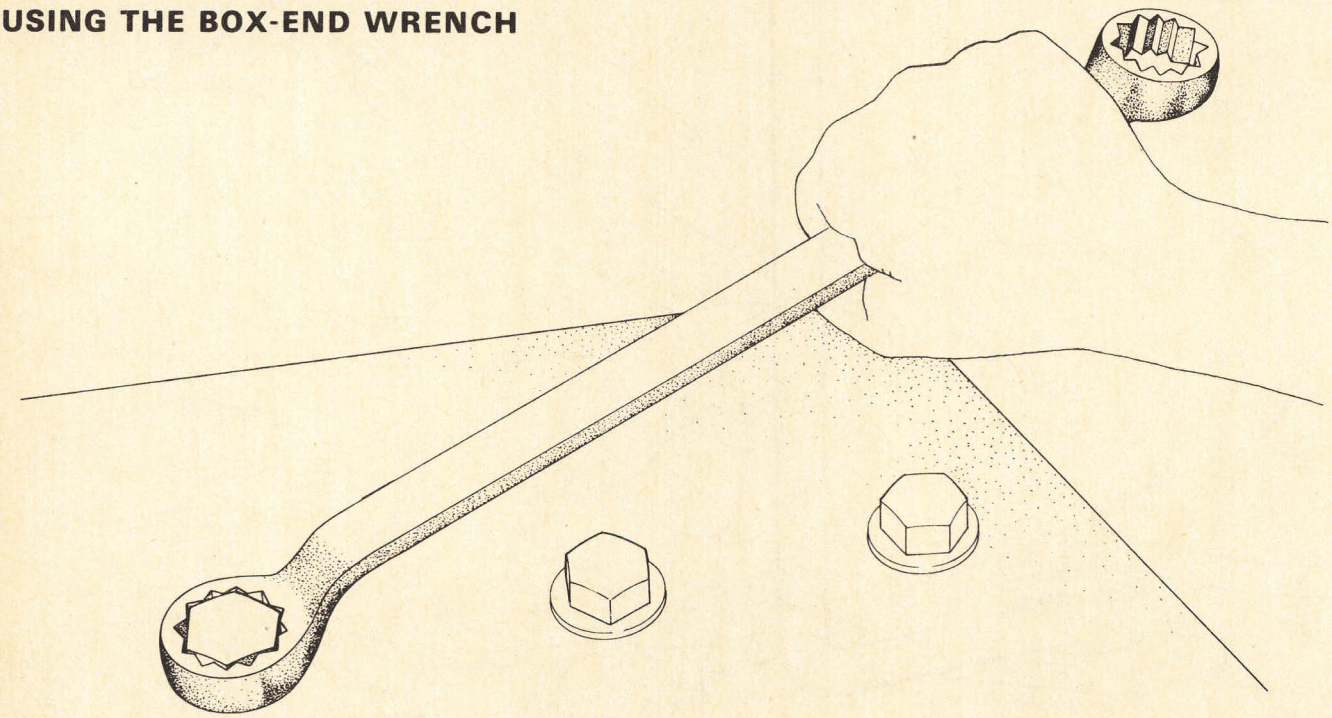


The ratcheting box-end wrench (A) can be a very handy item in the tool box. It is sold either in sets or individually and in either six-point or 12-point ratcheting boxes. The ratchet is fixed, which means it will only work in one direction. To reverse the direction, use the same end and simply flip the wrench over. Each end is a different size.

The ratcheting box-end wrench does have some limitations:

1. It is hard to use in tight spaces, due to the thick walls (B) surrounding the ratchet points.
2. Due to its construction, the ratcheting mechanism is naturally weaker, thus limiting the ratcheting box end to medium stresses only.
3. Not having an offset (angle) on the ratcheting box end limits its use to flat work only.

USING THE BOX-END WRENCH



Many things have been written on the simple subject of how to use wrenches. The very simplicity of this servant has caused most of the mechanical and non-mechanical world to assume that its correct handling is an automatic and natural function. This is not true.

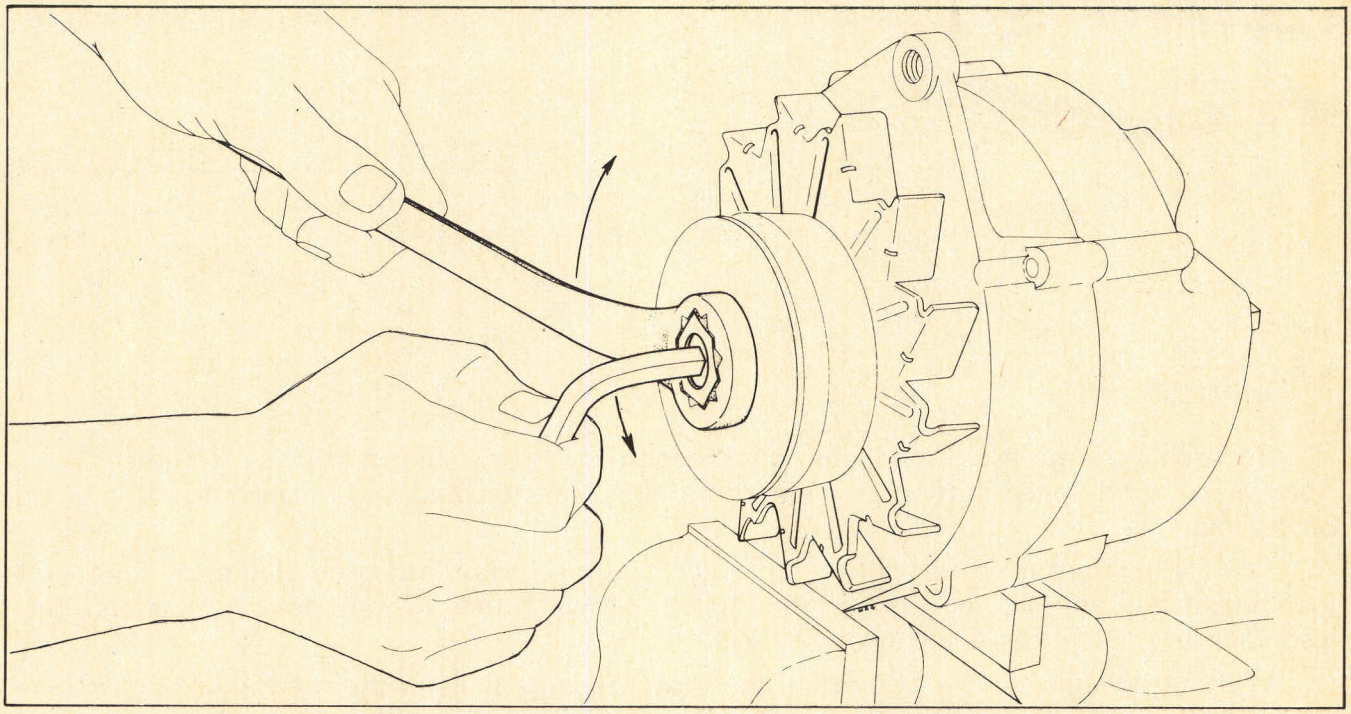
Too many tool users overrate their knowledge in the handling of wrenches, and the cost of their ignorance ranges from injured knuckles and bad language to actual loss of life.

In using wrenches of all types, it is important to select a wrench of the correct size. If too large a wrench is used, it will slip and wear off the corners of the nut or bolthead. This will cause difficulty when removing or tightening the nut or bolthead. Sudden slippage may also cause injury to yourself.

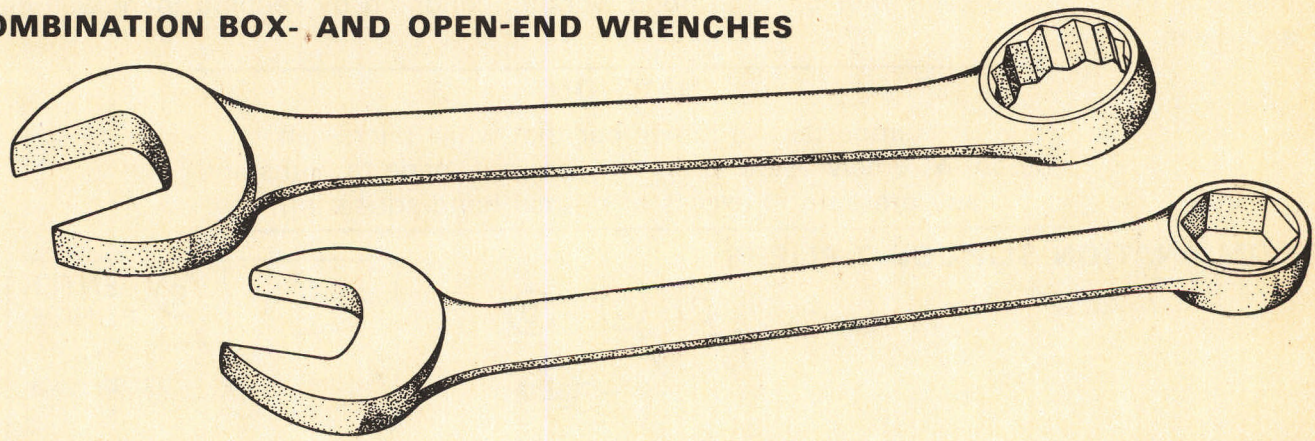
When applying any force to a box-end wrench, as with open-end wrenches, it is a good practice to always *pull* toward you. By pulling instead of pushing on the wrench, you can usually avoid hurting your hand if the wrench should slip. If it becomes necessary to push the wrench, always push with the palm of the hand, making sure the fingers are spread open to avoid skinned knuckles if the wrench slips.

Always be sure your hands are dry and the wrench is clean and dry before attempting to loosen a stubborn nut or bolt. Using a greasy or oily wrench increases the chances of slippage and possible skinned knuckles.

Also be sure your footing is good before attempting to pull on a nut or bolthead. Acquire the habit of figuring out ahead of time what will happen if the wrench slips, the threads strip or the bolt breaks. It may save you some pain.



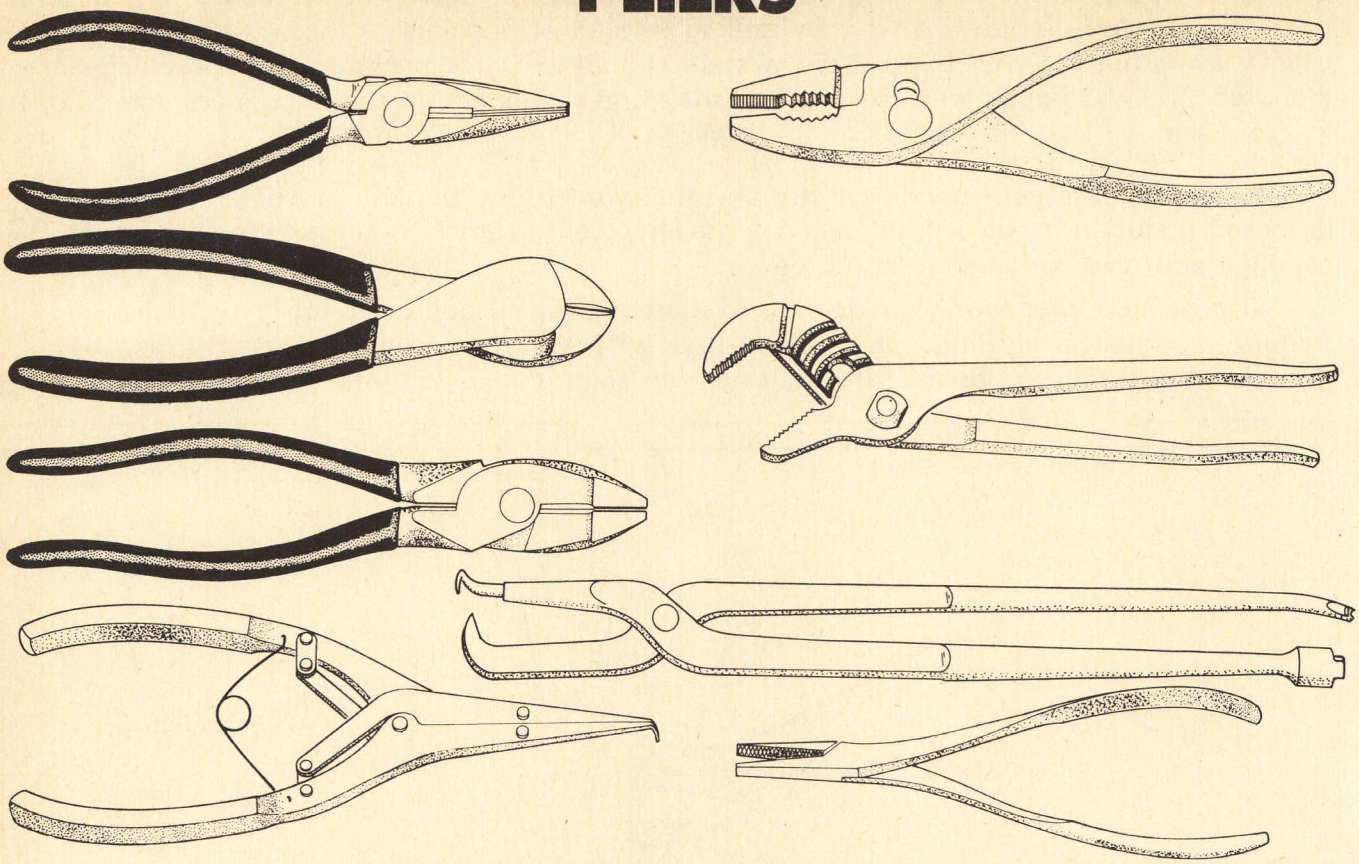
COMBINATION BOX- AND OPEN-END WRENCHES



All points discussed in the open-end and box-end wrench sections apply to the combination box- and open-end wrenches. This is a convenient type of wrench to have in your possession. It has the speed of the open-end wrench for running a nut or bolt down snug and the strength of the box-end wrench for completely tightening a nut or bolt.

This wrench is available with offset heads, different lengths, six- or 12-point heads and a wide selection of sizes. Try it; you'll like it!

PLIERS



Top-quality pliers are forged from hardened steel and machined to close tolerances. Some have hand-honed cutting edges and are polished, adjusted and inspected before going on the market.

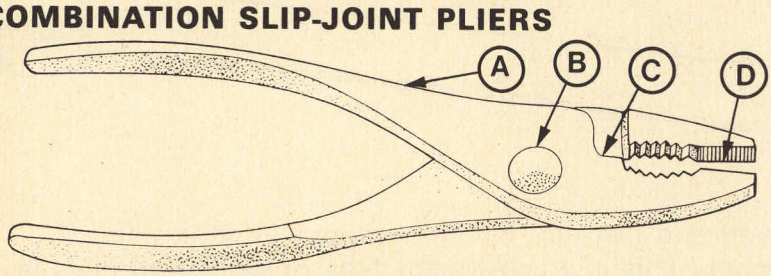
Pliers which are used to hold, bend, twist, pull or cut fall into two categories, solid joint (non-adjustable) and slip joint (adjustable), either of which may or may not have cutters. Pliers also vary in length from 4 inches to 20 inches.

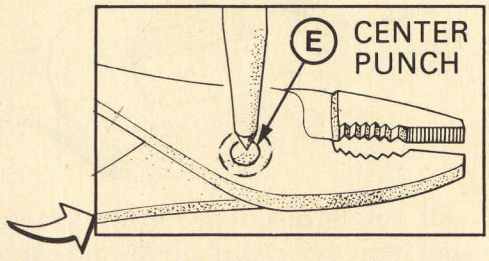
Without question, pliers are one of the most versatile tools in the mechanic's box. There are literally hundreds of different kinds, each designed for a special purpose. As with any tool, it is important to keep your pliers in good working condition by keeping them well oiled and clean.

CAUTION

It is important to remember that while pliers can be an extremely useful tool, they are not made to withstand any pressure in excess of normal hand squeezing.

COMBINATION SLIP-JOINT PLIERS





The combination slip-joint pliers (A) are general-purpose pliers. They can be adjusted to two or more sizes by means of a sliding pivot (B) which allows the jaws of the pliers to be opened wider for gripping items of a larger diameter. The jaws (D) have sharp, hardened cross teeth to grip the object on which you are working. Usually a short shearing edge (C) for cutting wire is found on this type of pliers.

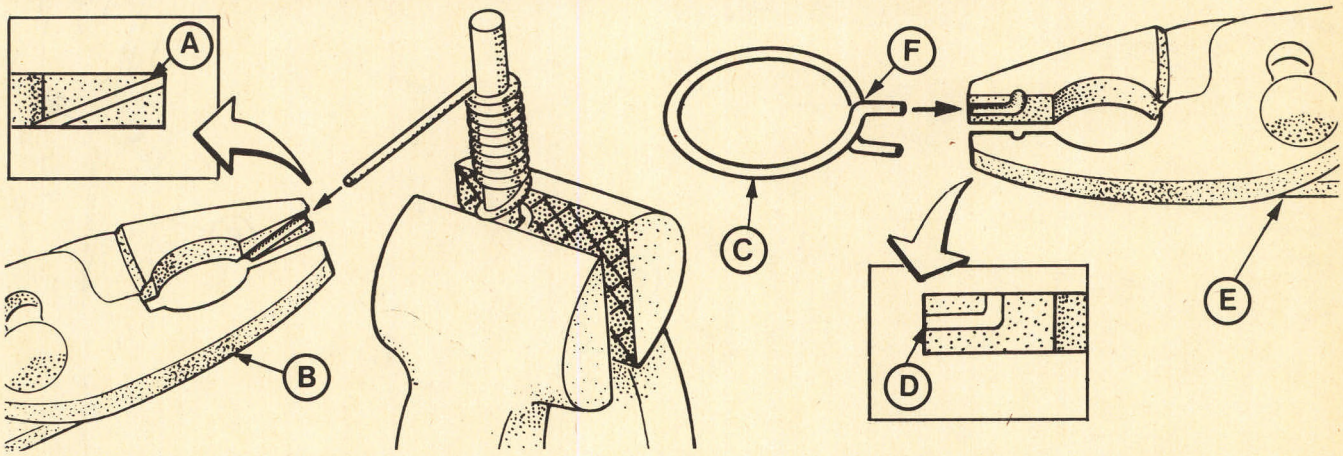
CAUTION

When using combination slip-joint pliers on nickel, chrome or any other finish that is easily marred, use cardboard or tape to act as a pad between the jaws (D) and the material on which you are working.

Never use combination slip-joint pliers for turning nuts or bolts, as this will round off the corners and badly mar the nut or bolt.

Eventually the slip-joint (B) of the pliers may become loose through usage and must be tightened. If this happens, simply tighten the nut (E) to the desired setting (just snug) and wedge it in place, using a center punch and hammer.

SLIP-JOINT COIL SPRING PLIERS AND WIRE HOSE CLAMP PLIERS

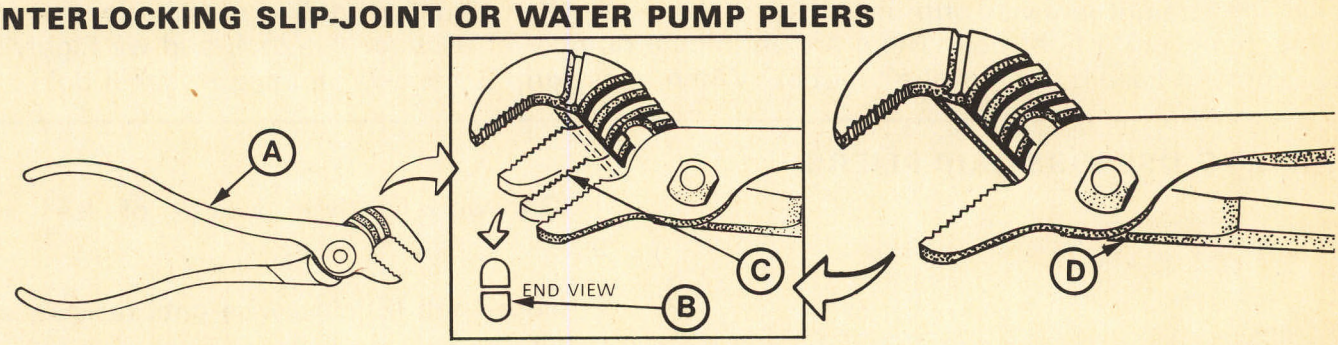


There are many variations of combination slip-joint pliers. Two of the most popular are the coil spring pliers (B) and the wire hose clamp pliers (E).

Coil spring pliers (B) have a groove cut into one jaw (A) to allow the mechanic to grip the spring material solidly while winding it around the material on which he is working.

Wire hose clamp pliers (E) have a groove cut into both jaws (D). This groove permits a firm grip on clamp ends (F). To operate this tool, simply grip the clamp (C) with one clamp end in the groove of each jaw and squeeze. This will open the clamp to a larger diameter, making it easy to remove or install hose clamps such as those on radiator hoses.

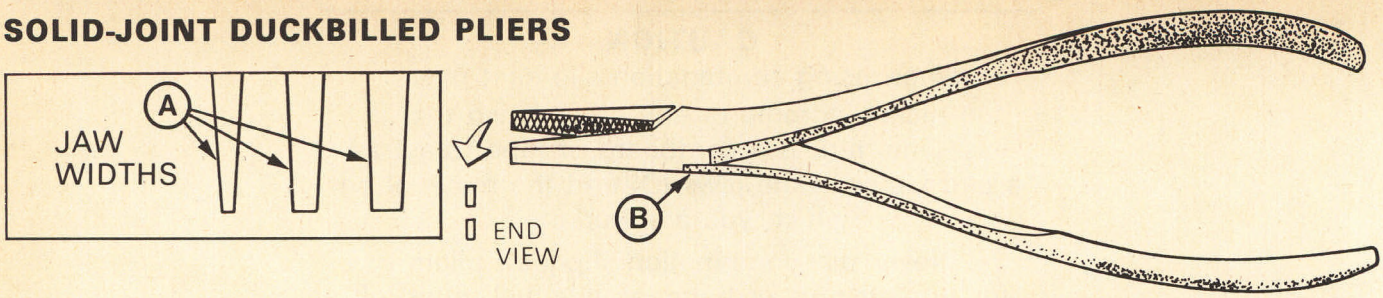
INTERLOCKING SLIP-JOINT OR WATER PUMP PLIERS



Another popular variation of the combination slip-joint pliers is the interlocking slip-joint or water pump pliers (D), which are very useful for gripping large or hard-to-get-at objects. These pliers can be opened to a number of wider positions (C) while the jaws remain parallel (B) to each other. Because of the larger bite available with these pliers, the handles are made longer to provide greater leverage. They are also available in a miniature size (A) used specifically for small electrical work.

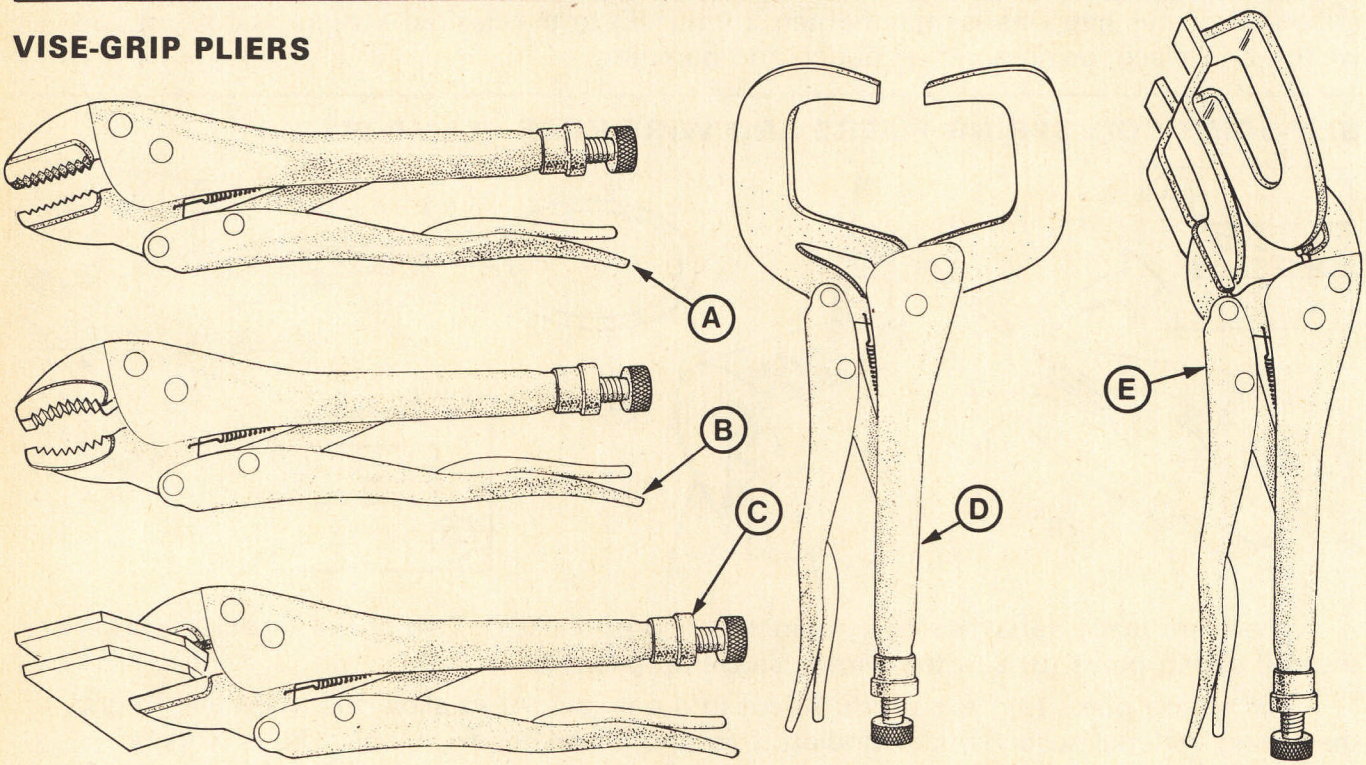
PLIERS

SOLID-JOINT DUCKBILLED PLIERS



The duckbilled pliers (B) are another general-purpose tool. This tool has a solid joint and comes in many lengths and jaw widths (A). Duckbilled pliers are great for reaching small objects in tight places or for bending cotter key ends.

VISE-GRIP PLIERS

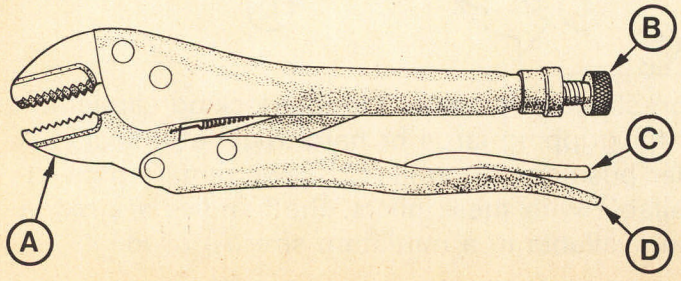


Vise-grip pliers (A) through (E) are useful for holding work together while another task is being performed on the work.

Again, there are many varieties of vise-grip pliers. Some of the more popular ones are straight jaw (A), curved jaw (B), bending tool (C), vise-grip C-clamp (D) and welding pliers (E).

The straight jaw vise-grip pliers (A) can be especially useful for holding nuts stationary while removing a tight bolt. There are an infinite number of uses for this tool, and we highly recommend keeping one in the tool box. When a vise-grip is needed, nothing else will do!

HOW TO USE VISE-GRIP PLIERS



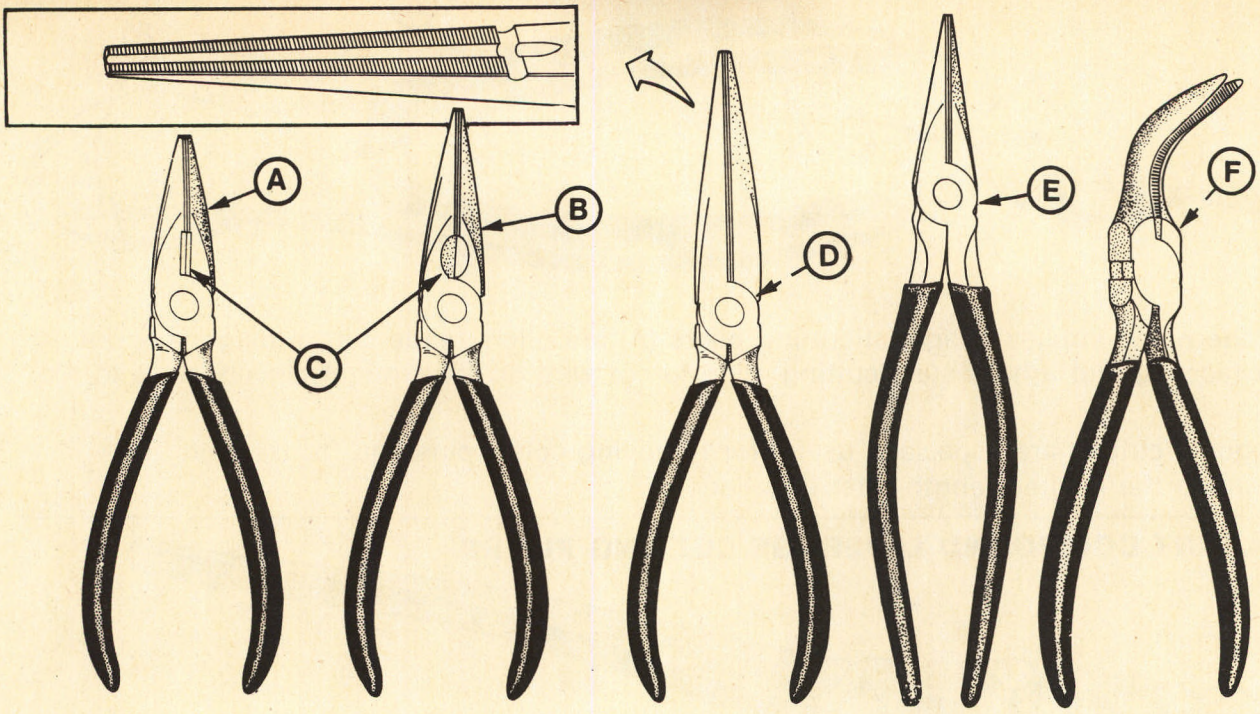
1. Grip work lightly in jaws (A) of vise grips.

2. Turn knob (B) clockwise until resistance is felt.

3. Squeeze vise grips until click is felt (it should require a hard squeeze).

4. To release, simply squeeze lever (C) against handle (D).

SOLID-JOINT LONG OR NEEDLE-NOSED PLIERS

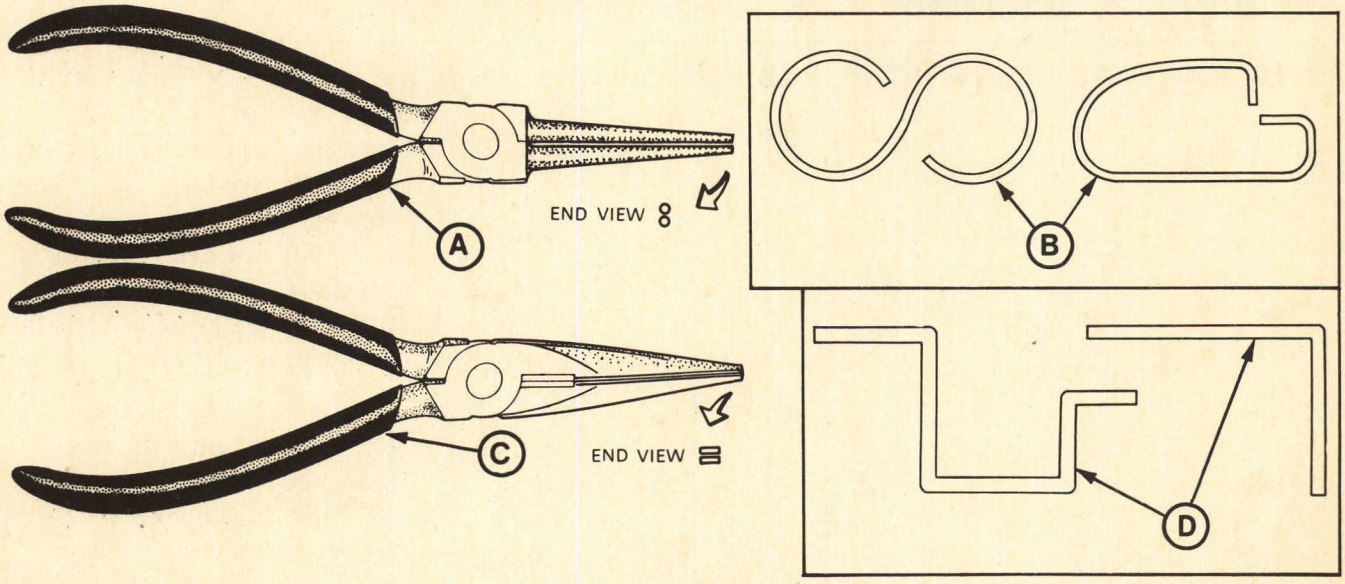


Long or needle-nosed pliers (A) through (F) are very handy for getting at those small, hard-to-reach areas. They come in a variety of sizes and styles, some incorporating a cutting surface (C) for cutting wire (also known as long or needle-nosed diagonal cutters).

Needle-nosed pliers are used for a variety of work, but most often in electrical work.

WARNING

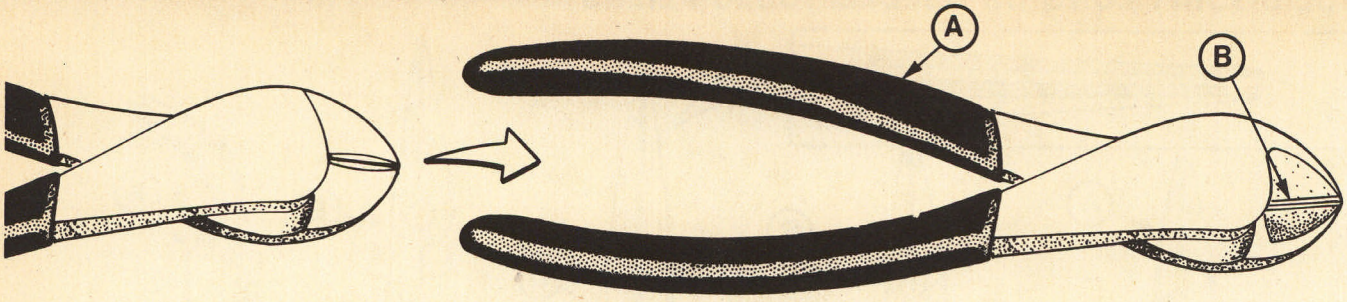
BE SURE TO USE PLIERS WITH AN INSULATED HANDLE WHEN WORKING AROUND ELECTRICITY TO PREVENT POSSIBLE ELECTRICAL SHOCK. THESE HANDLES ARE COATED WITH RUBBER, VINYL OR OTHER NON-CONDUCTIVE MATERIAL.



Many needle-nosed pliers have rounded jaws that are useful in bending wire into curves or circles (B). These are called round-nose pliers (A). Other needle-nosed pliers have square jaws (C) for making sharp bends (D) in wire. These are called long chain-nosed pliers.

PLIERS

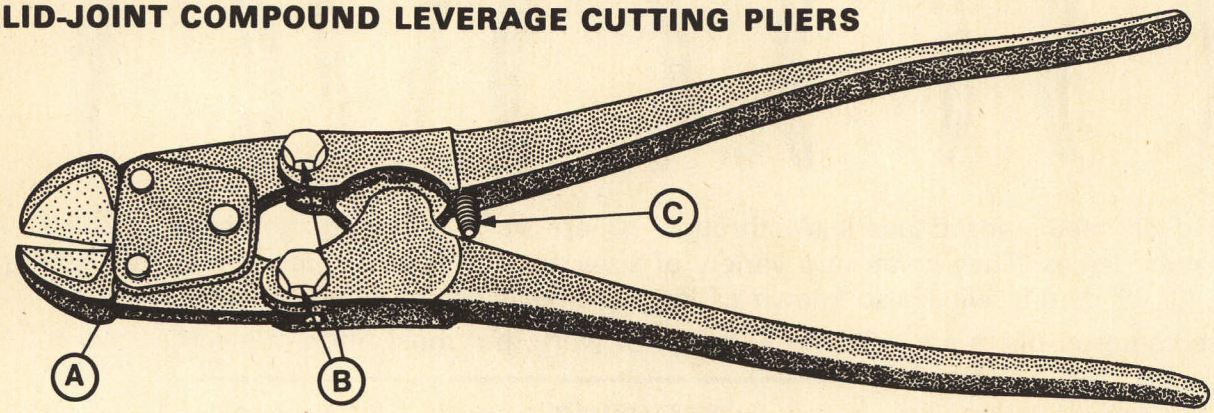
SOLID-JOINT DIAGONAL CUTTING PLIERS



As the name implies, diagonal cutting pliers (A) are pliers made with a diagonally cut head or face (B) and a hard steel cutting edge to cut wire or other metal objects close to the surface.

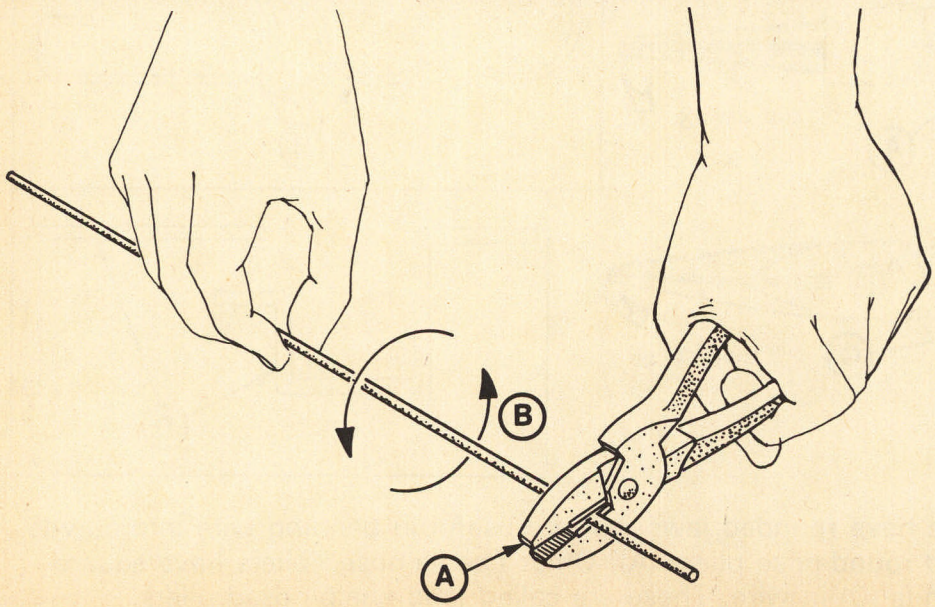
Diagonal cutters are especially useful for removing cotter pins and for trimming new cotter pins to the desired length after installation.

SOLID-JOINT COMPOUND LEVERAGE CUTTING PLIERS



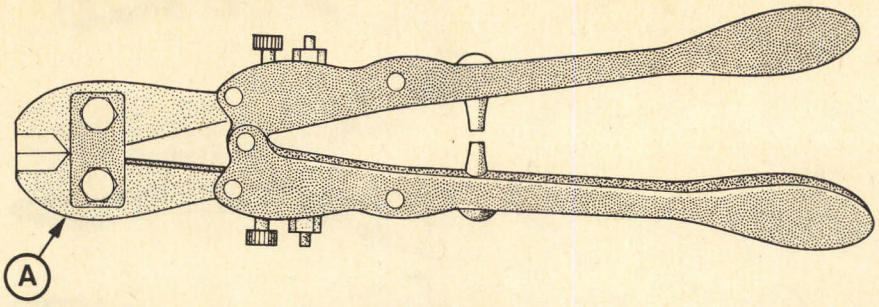
For those tough cutting jobs, compound leverage diagonal cutters (A) are recommended. Compound refers to the combination of additional leverage which is gained through a series of hinged arms (B). These cutters are designed to provide tremendous power for cutting large wire and small- to medium-sized bolts. Most compound leverage cutters have an adjustable stop (C) to prevent the cutting surfaces from touching each other, thereby preventing extra wear on the cutting edges. These cutters provide approximately four times the cutting power of the standard diagonal cutters.

SOLID-JOINT SIDE-CUTTING PLIERS: Side-cutting pliers (A) are a very useful all-around tool. They are a heavy, strongly built tool made for gripping, twisting, light hammering and cutting. They will not cut as close to a surface as will diagonal cutting pliers, but are useful in many other ways.

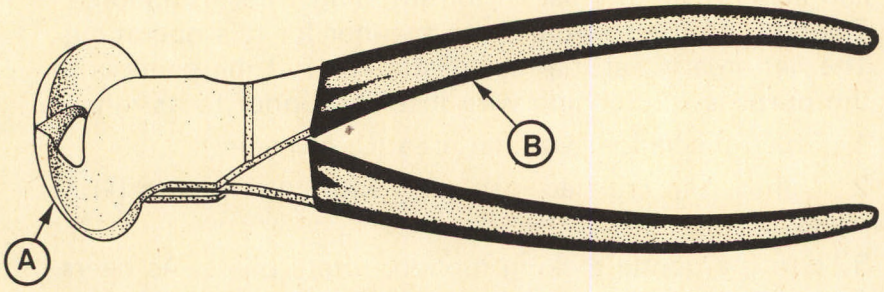


To cut wire or small round stock with these pliers, cut around the wire (B), making successively deeper bites with each revolution. Do not rock the cutter sideways while rotating it or damage to the material will result.

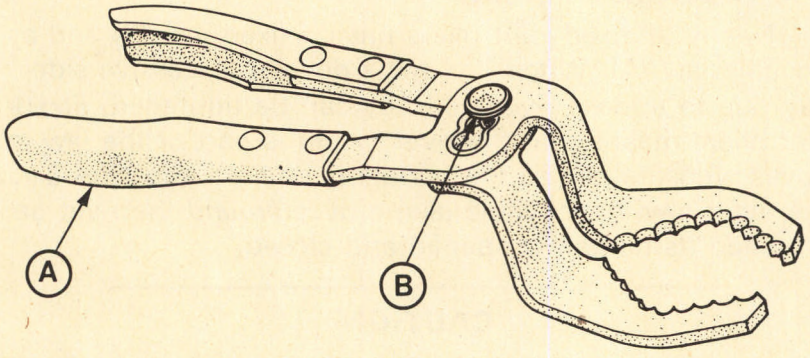
SOLID-JOINT COMPOUND LEVERAGE BOLT CUTTERS: For the really tough jobs, such as cutting large bolts, cables, rods, etc., the compound leverage bolt cutters (A) are extremely useful. They can handle the toughest cutting job with a minimum of effort. Some models have replaceable jaws, which make the tool last indefinitely.



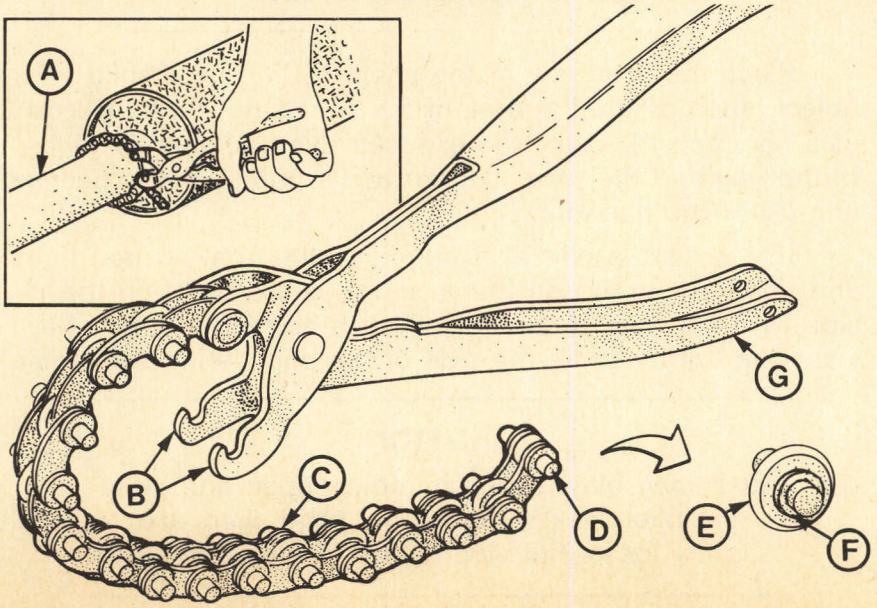
SOLID-JOINT END-CUTTING PLIERS: Solid-joint end-cutting pliers (B) provide excellent leverage for cutting objects extremely close to the surface. The curved front surface of the jaws (A) also acts as a fulcrum (axis or pivot point), which is handy for prying loose and removing tacks and staples in automobile upholstery.



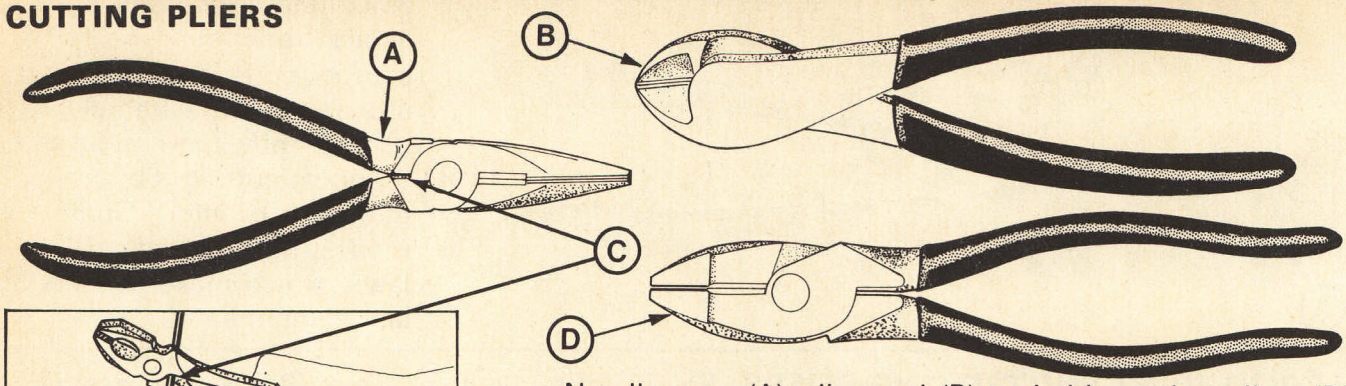
SLIP-JOINT RADIATOR HOSE PLIERS: This pair of pliers (A) is great to have around during water pump removals, radiator repairs or engine overhauls. These pliers can adjust, using the slip joint (B), to cover almost any size radiator hose on the market today. After just a few twists of the pliers, the hose is completely free from gasket glue or frozen connections, making your job easier.

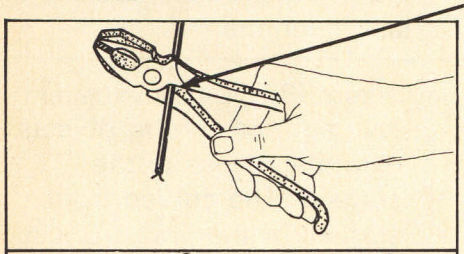


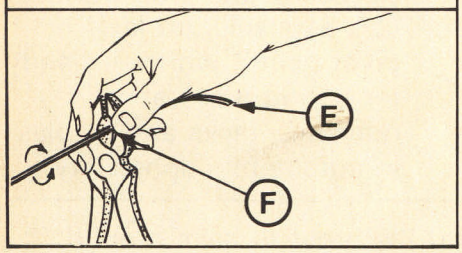
EXHAUST AND TAILPIPE CUTTER PLIERS: This tool (G) is a must if you do exhaust system work on any vehicle. It is adjustable for pipe sizes from 3/4-inch up to 2-5/8 inches and has cutters (E) around the links (C). To use this tool, simply place the links around the pipe (A) and pull them tight, placing the tip (D) of the last link nearest the pipe into the jaws (B) of the pliers. Only 90° handle movement is needed to cut through any pipe. There is a special ''Lock-Guard'' (F) featured in each link that controls the cutting depth of the pliers.



HOW TO STRIP WIRE INSULATION WITH NEEDLE-NOSE, DIAGONAL OR SIDE-CUTTING PLIERS



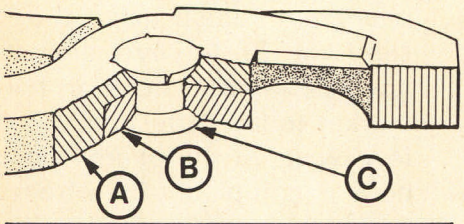




Needle-nose (A), diagonal (B) and side-cutting pliers (D) can also prove very useful for stripping wire insulation. They are all used in the same manner for this operation. The flat area (C) at the rear of the head of the pliers is for the purpose of crushing wire insulation prior to its removal.

1. Crush insulation with flat area (C) of pliers.
2. Lightly grip crushed insulation with cutting jaws (F) of pliers.
3. Using a gentle rocking motion, rotate pliers. As pliers are rotated, insulation will be cut. Gently pull sideways on pliers to strip away insulation (E).

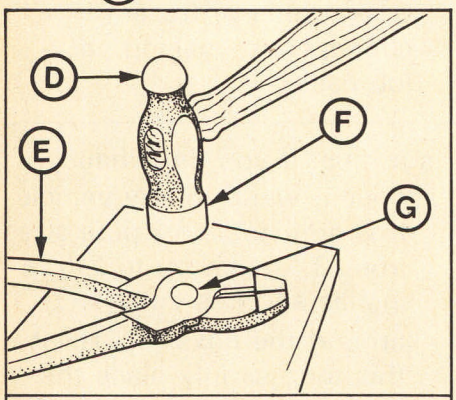
HOW TO TIGHTEN OR LOOSEN FIXED-JOINT PLIERS



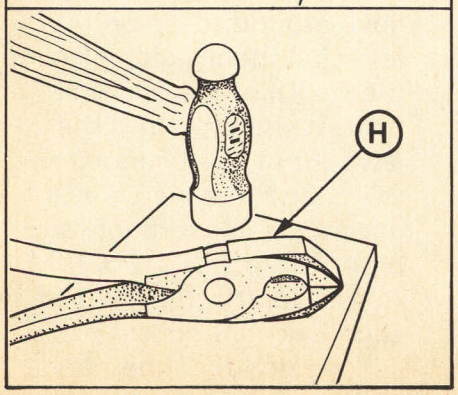
Nearly all fixed-joint pliers have a fixed jaw (B) and a movable jaw (A). When the pliers develop excessive side-play due to a loose rivet (C), they can be tightened. Fixed-joint pliers means that the rivet or pin is part of the jaw and moves with the jaw as the handle is opened and closed. The other jaw (or movable jaw) moves *around* the rivet or pin when its handle is opened and closed.

CAUTION

After *each* blow of the hammer, open and close the pliers several times until the desired tightness is reached.



Place the fixed jaw of the pliers (E) flat on a solid object, such as the flat area of a vise. Using the large end of a hammer (F), strike the exposed rivet (G) sharply to further expand the rivet. Do not use a punch or the peening end (D) of the hammer.

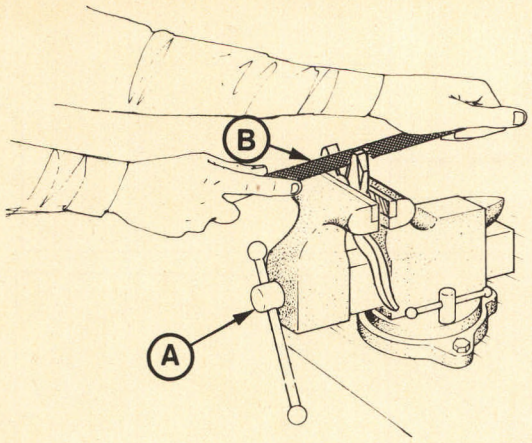


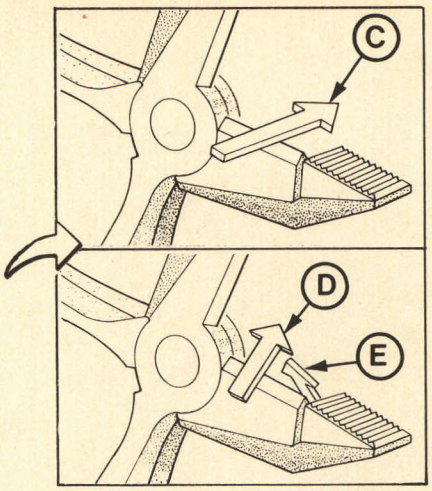
If you have a pair of fixed-joint pliers that are too tight and you wish to loosen them, simply place them on their side (H) on a hard metal object (such as the flat area of a vise) and lightly strike the side of the pliers with a hammer.

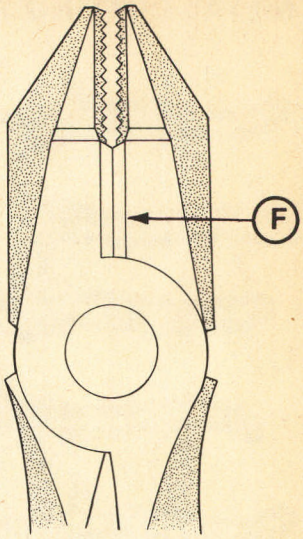
CAUTION

After *each* blow of the hammer, open and close the pliers several times until the pliers are slightly loose (not sloppy) and are easy to use.

HOW TO SHARPEN DIAGONAL AND SIDE-CUTTING PLIERS



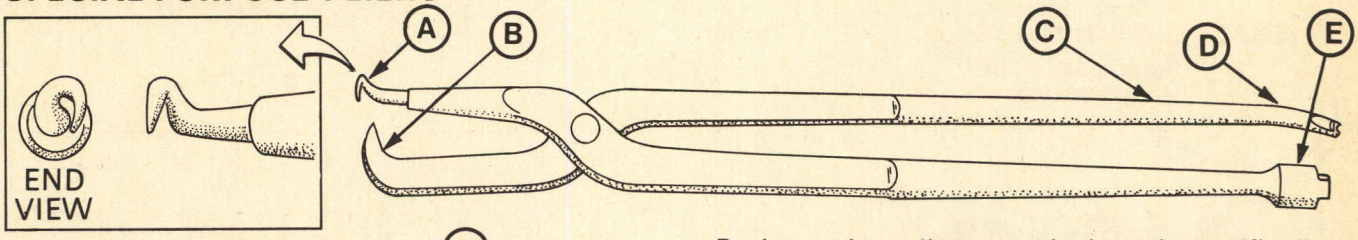


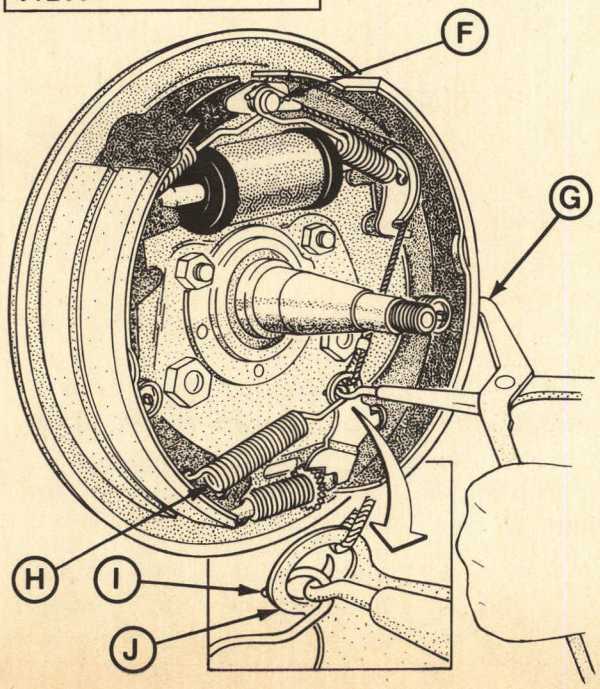


Most side-cutting and diagonal-cutting pliers can be resharpened if dull or nicked. When sharpening cutters, use a fine, single-cut, half-round file or a very fine abrasive stone. The degree of hardness of cutting pliers is slightly less than that of files, so you should have no trouble removing damaged metal.

First, place the pliers in a vise (A) and carefully file straight and level across both cutting edges of the jaws (B, C) to remove any nicks. Then lightly file both the inside (E) and the outside (D) bevels (angles) as close as possible to the original bevels. After performing these three filing steps, close the cutting pliers and hold them to the light. You should not be able to see any light through the cutting edges (F). Repeat the filing process until you have achieved a good cutting edge and the cutting edges are ''light-tight'' when the pliers are closed.

SPECIAL-PURPOSE PLIERS

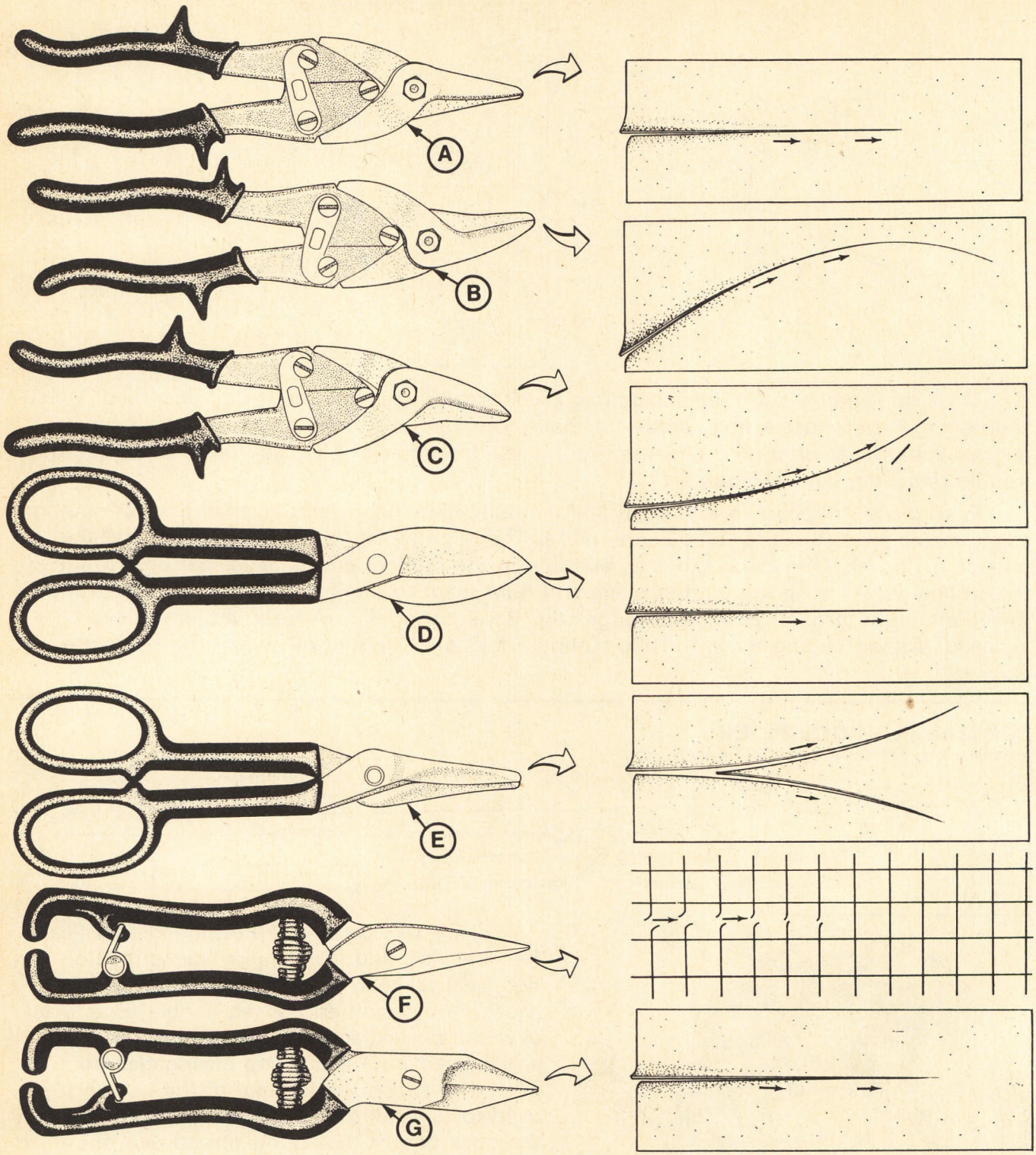




Brake spring pliers are designed specifically for removing and installing brake springs on Bendix, Lockheed and other types of brake shoes. The socket end of the handle (E) is placed over the post attached to the brake spring (F) and rotated until the spring disengages from the post. The spoon-shaped end of the handle (D) is used to reinstall the spring on the post (F). With the hook end of the spring placed over the handle at point (C) and the spoon-shaped end (D) positioned over the post, lift until the hook slides down the handle and engages post (F).

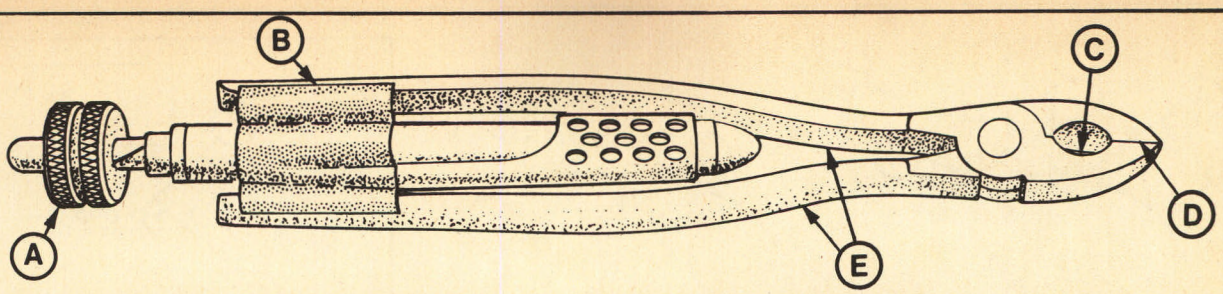
The head of the tool is used to disengage the long spring (H) stretched between the two brake shoes. The pointed end (B) is placed on the brake shoe at position (G). The hooked end of the tool (A) is placed under hook of spring (I). The tool is then squeezed until spring hook (I) is disengaged from hole (J).

METAL-CUTTING SNIPS AND SHEARS

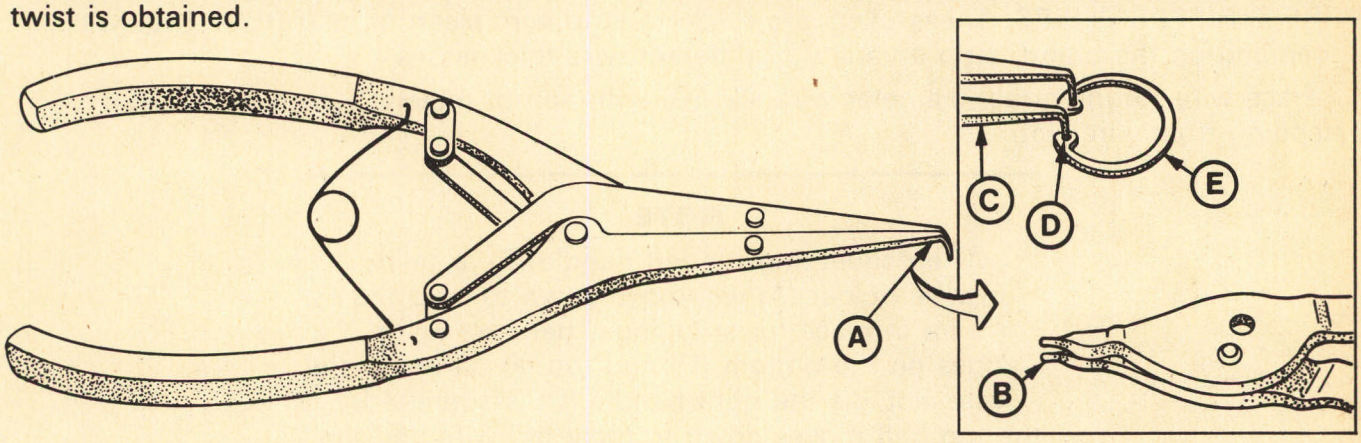


Aviation snips (A), (B) and (C) are excellent tools for cutting 18-gauge or heavier cold rolled steel sheets. They are also useful for cutting sheet aluminum, brass, copper, etc. The straight-cut aviation snips (A) are made to cut in a straight line. The right-cutting aviation snips (B) cut to the right, and the left-cutting aviation snips (C) cut to the left. The right- and left-cutting snips are useful for cutting curves and circles in metal.

For cutting lighter materials such as light sheet metal, wire, gasket material and rubber, the straight snip (D) or duckbill snip (E) is recommended. Like the aviation snips, the straight snip (D) cuts in a straight line, and the duckbill snip (E) cuts in a curve (in either direction). For cutting extra-light sheet metal and wire, the cutting shears (F) and (G) are best.

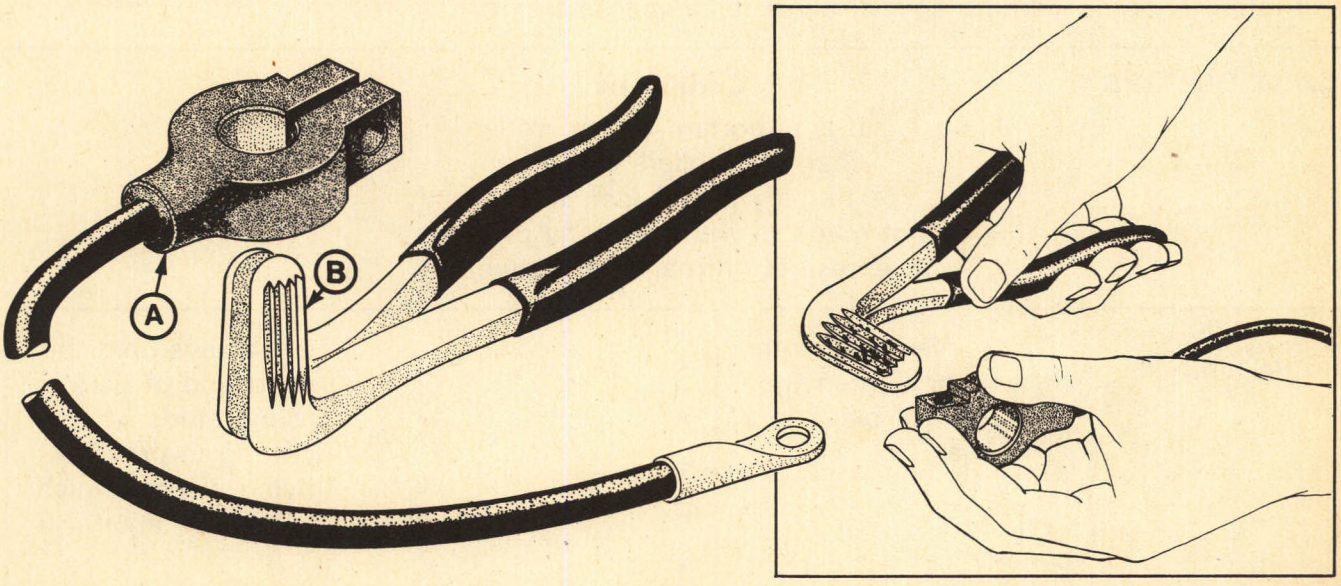


WIRE TWISTERS: These twisters are used specifically for removing and installing safety wire. The wire twisters usually incorporate a diagonal cutter (C) on the head of the tool for cutting the wire. To use the tool, clamp the two wire ends between the jaws (D) of the wire twisters. Squeeze the handles (E) together and lock them in place by moving slide (B) forward. Pull the knob (A) repeatedly, allowing twisters to spin freely until desired amount of twist is obtained.

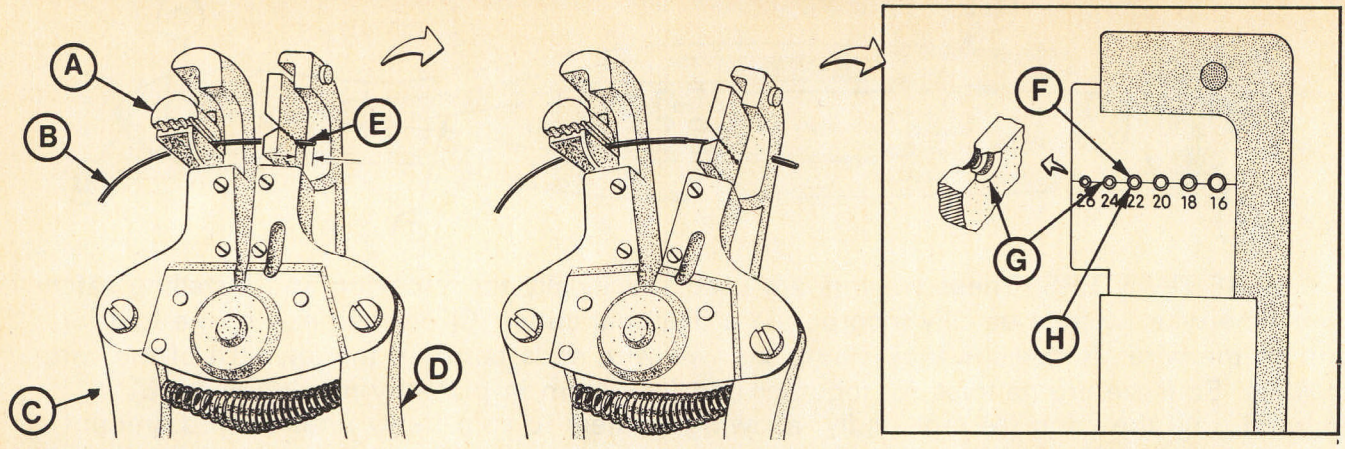


LOCK RING PLIERS: These pliers, also called snap ring pliers, are made for removing and installing external lock rings (E). By placing small 90° tongs (C) of pliers in lock ring eyes (D) and squeezing the handles, the lock ring (E) will spread open for easy removal or installation.

Snap ring pliers are available with straight tips (B) as well as the 90° tips (A). There are also snap ring pliers made for internal snap rings. These pliers work like the external pliers mentioned above except that they are normally in an open position. When squeezed, they close the snap ring, allowing removal.



BATTERY TERMINAL SPREADER: This tool is made for cleaning and spreading battery terminal clamps (A) which are corroded shut. As the pliers rotate inside the battery terminal clamp, the sharp teeth (B) clean the terminal. If the terminal is tightly closed, it can be opened by spreading the handles.



WIRE-STRIPPER PLIERS: These pliers are made to strip wire clean of insulation. They will, depending on the brand, strip a variety of different wire thicknesses.

1. Place wire (B) in correct diameter wire slot (G) with approximately ¼-inch of wire (E) extending from wire slot.

NOTE

When squeezing the left handle (C), a built-in wire holder (A) will move down to hold the wire in place for stripping. There are knife edges on the bottom (H) and top (F) halves of the wire slot. As the right handle (D) is squeezed, the top half moves down to meet the wire and the bottom half. With a continuation of the squeezing, the two halves meet and automatically strip the insulation from the wire.

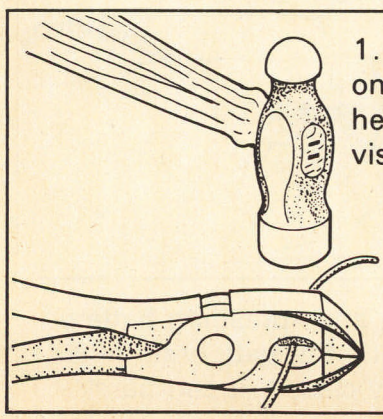
2. Squeeze handles and strip wire.

As we have indicated, there are many thousands of different kinds of pliers on the market today, and we have shown just a few. There are pliers made for almost *every* kind of mechanical task. Be sure to contact your favorite tool manufacturer or distributor if you desire any information concerning special pliers for a special task.

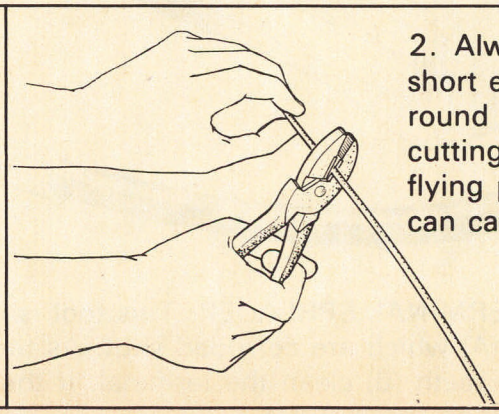
CAUTION TIPS

CAUTION

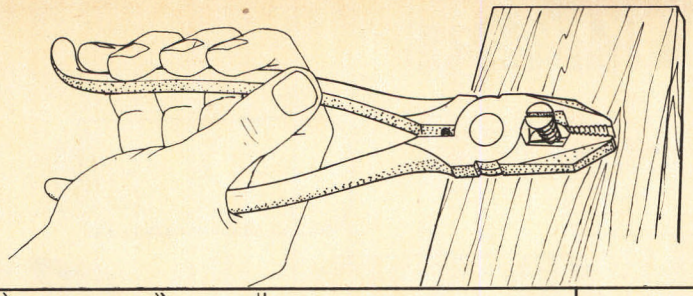
It is important to remember that while pliers can be an extremely useful tool, they are not made to withstand any pressure in excess of normal hand squeezing.



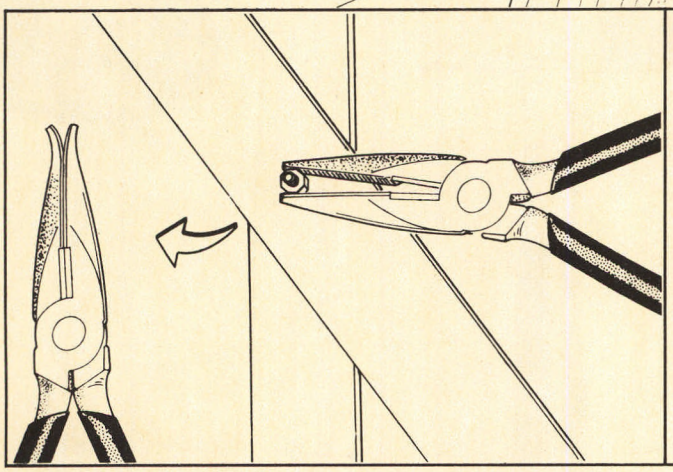
1. Never hammer on or tighten the head of pliers in a vise.

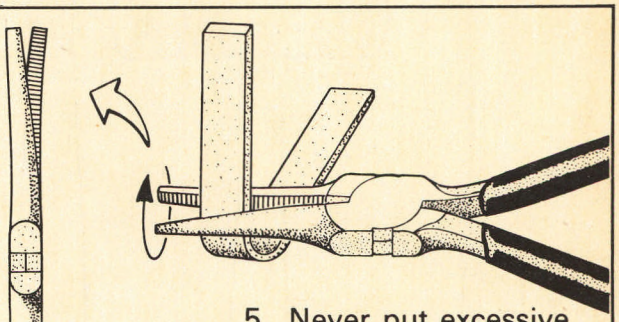


2. Always hold the short end of wire or round studs when cutting to prevent flying pieces, which can cause injury.

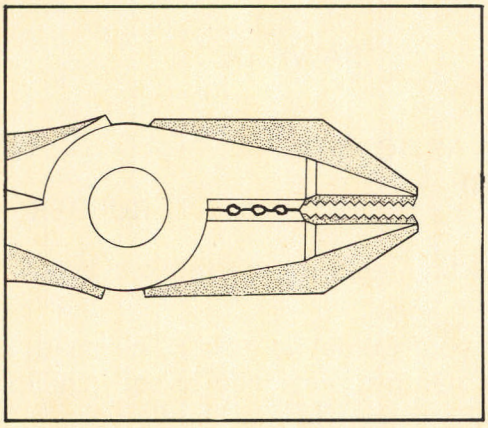


3. Except for the compound leverage cutting pliers, never attempt to cut large screws or bolts with a pair of cutting pliers.





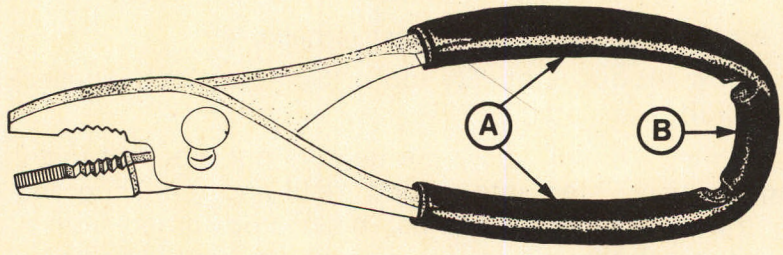
5. Never put excessive side pressure on needle-nose pliers. Damage to pliers will result.

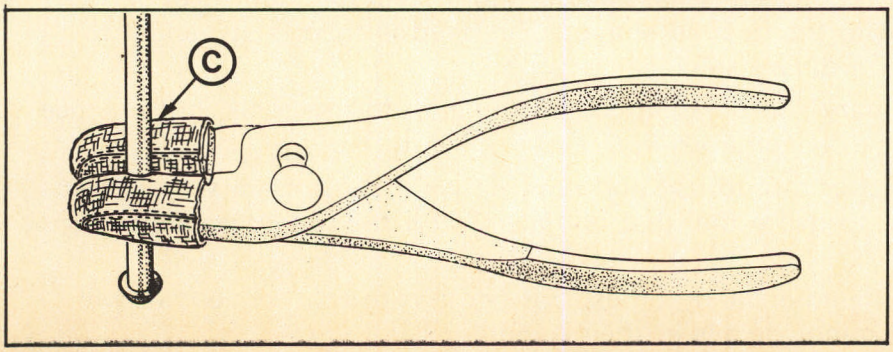


WARNING

NEVER ATTEMPT TO CUT WIRE WITH ELECTRICAL CURRENT FLOWING THROUGH IT. PERSONAL INJURY OR DEATH CAN RESULT. IF WIRE IS CUT WITH ELECTRICAL POWER ON, SMALL GOUGES OR HOLES WILL BE BURNT INTO THE CUTTING EDGES OF YOUR CUTTER. THIS DAMAGE IS PERMANENT. WHEN WORKING AROUND ELECTRICITY, ALWAYS USE PLIERS WITH INSULATED HANDLES TO PREVENT SHOCK.

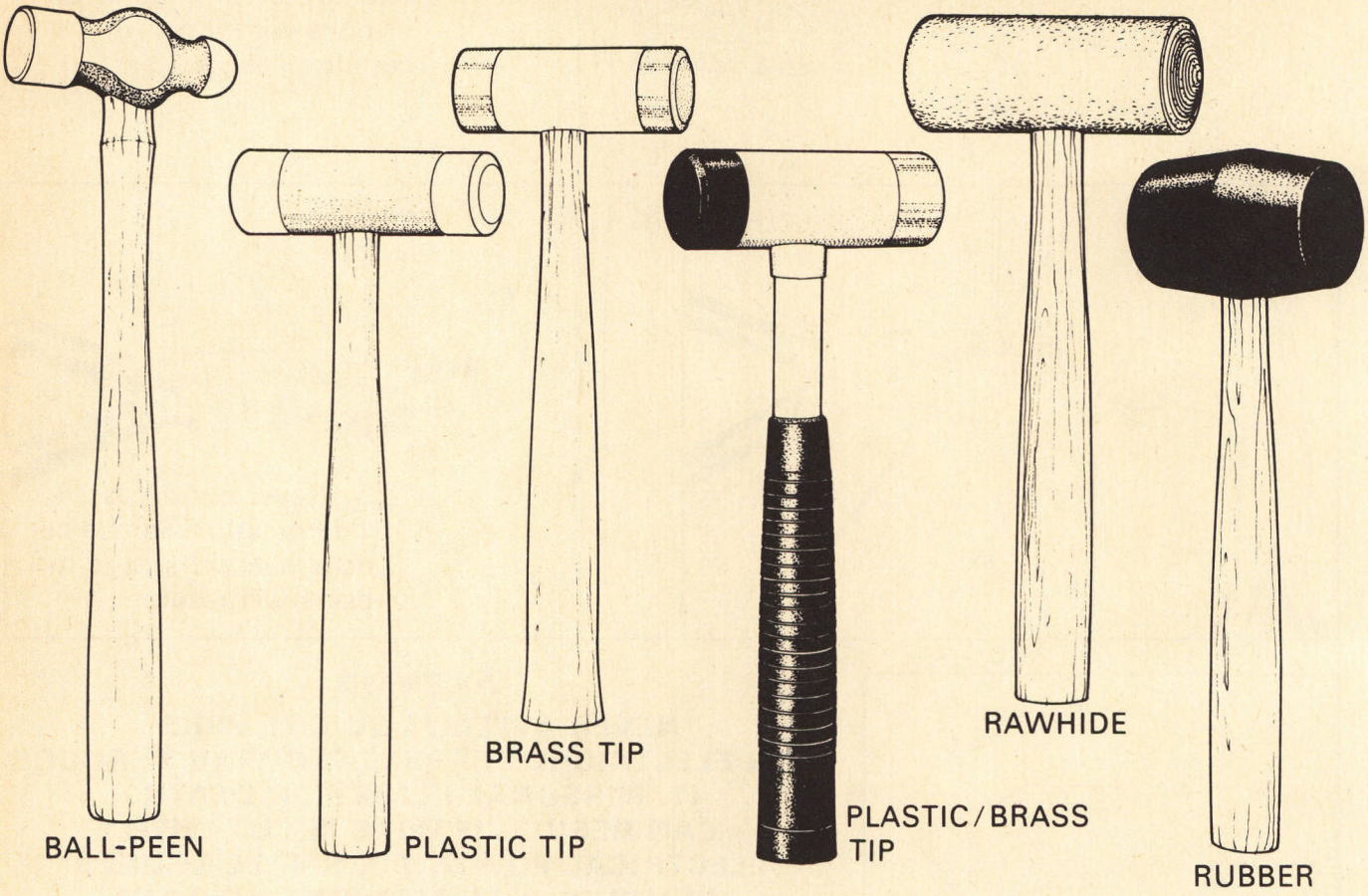
HANDY HINTS: 1. To insulate your pliers as well as make them spring open automatically with each use, cut a small piece of rubber or plastic hose (B) approximately 6 inches long. Slip each end of the hose on both handles (A) of your pliers, approximately halfway up. You now have an electrically safe pair of "quick-opening" pliers.





2. To prevent marring the material on which you are working with the jaw teeth of a pair of pliers, simply snip off a couple of the fingers from a pair of old gloves and slip them over the jaws (C) of the pliers.

HAMMERS



As you know, there are hundreds of sizes and shapes of hammers on the market. We will discuss only the ones most widely used in the automotive field.

Never purchase a cheaply made hammer. (Price will be your guideline here.) The heads are made of poor grade steel and can chip or fall apart. The handles are made of soft, cheap wood which splinters easily under strain. The head is usually attached to the handle very poorly, allowing the head to fly off when striking a blow. This can cause severe injury.

Qualities to look for in a well made hammer are:

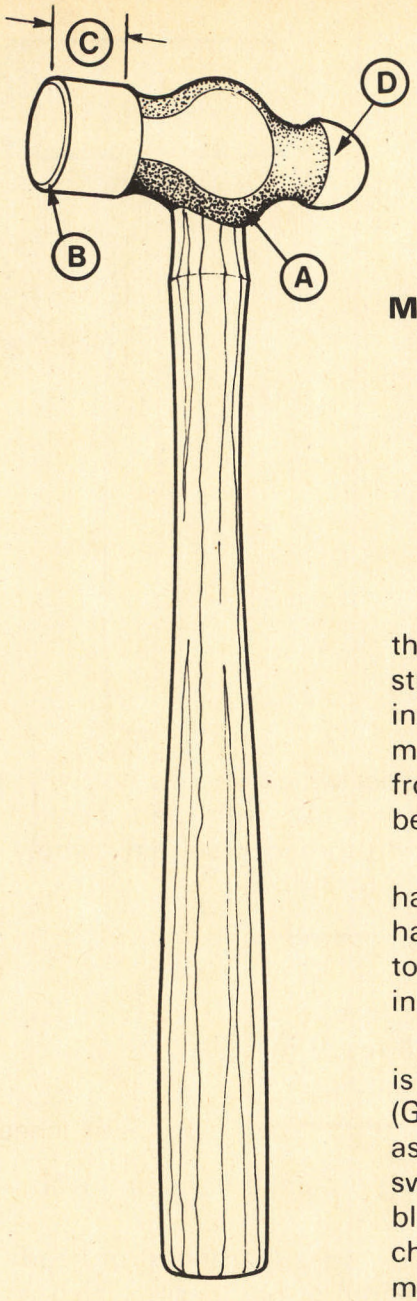
- Method of attachment of the hammer head to the handle.
- The type of wood of which the handle is made. (The best is hickory.)
- A good brand name, one you know produces quality tools. (Some are: Channellock, Stanley, Snap-on, Proto, Sears Craftsman, etc.)

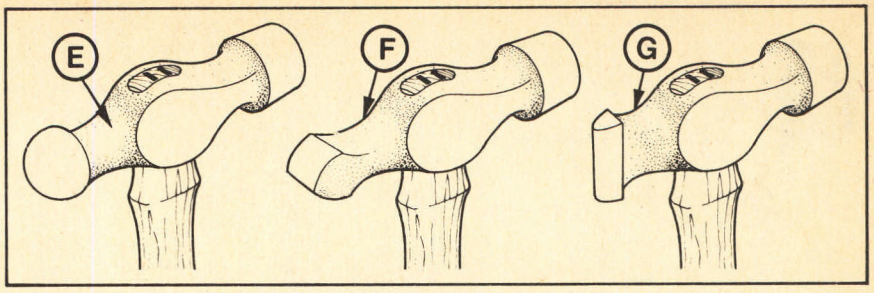
By purchasing a brand name hammer, you will know the head is not made of just cast steel. Cast steel is made by pouring white-hot steel into a sand mold and removing and trimming it when cool. A good brand name hammer head has been drop-forged from tough alloy steel. Drop-forged steel is red-hot steel hammered into a steel die, cooled under a special process and then ground to the desired shape. The head is then heat treated to obtain a steel twice as strong as ordinary steel.

Anyone who possesses ordinary coordination can easily learn to use tools, but practice and proper instruction is a must to become *skillful.*

Skill means knowing the proper tool to use and how to use it the correct way. It also means a positive willingness not to use a tool that is not right for the job. Hammers are no exception.

No doubt you have used a hammer many times, but perhaps in this section we will remind you of some overlooked minor details in their handling.





MACHINIST'S HAMMERS

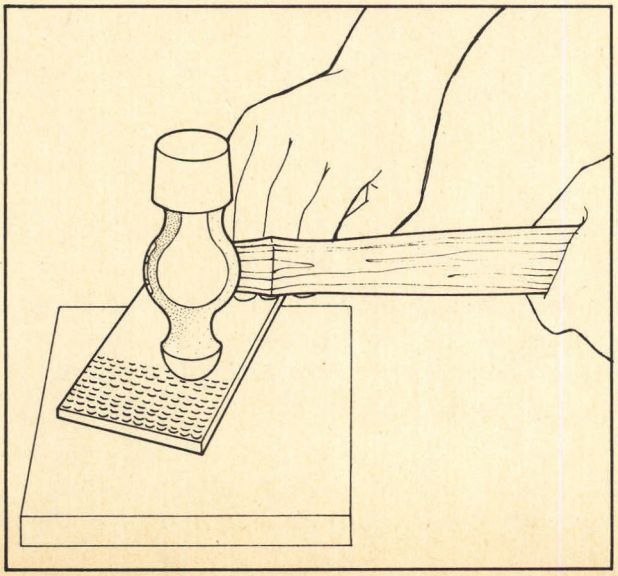
The principal parts of the machinist's hammer are:

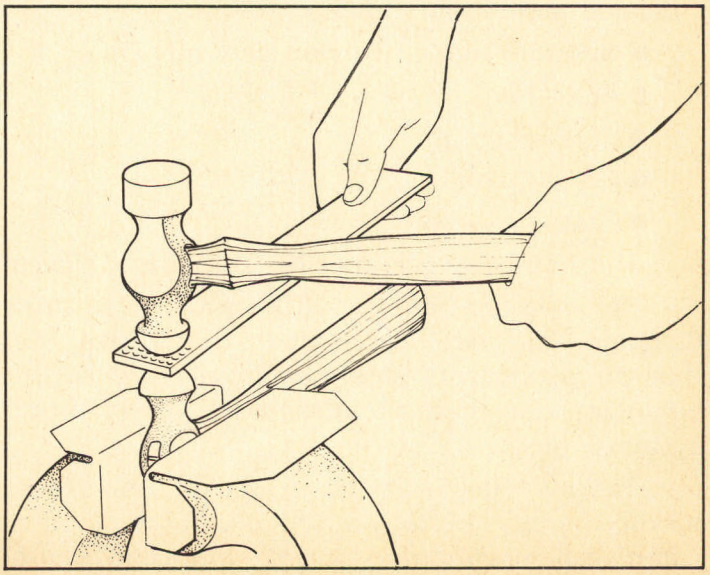
- The peen (D).
- The eye (A). (The open end of the head into which the handle fits.)
- The post (C).
- The face (B).

The three most common types of machinist's hammers are the ball-peen (also spelled pein) (E), the cross-peen (F) and the straight-peen (G). The word "peen" means "shaped for indenting or chipping." The size of the peen hammer is measured by the weight of the head in ounces (oz.). They range from 2 oz. up to 48 oz. (3 lbs.), the most commonly used range being 8 oz. up to 16 oz.

As you can see by the illustration, the ball-peen hammer (E) has a rounded ball on one end of the head. This is used for hammering the end of a bolt or stud until the metal has swelled to the point where it will not jar loose. It is also used for pounding out rounded and flat surfaces.

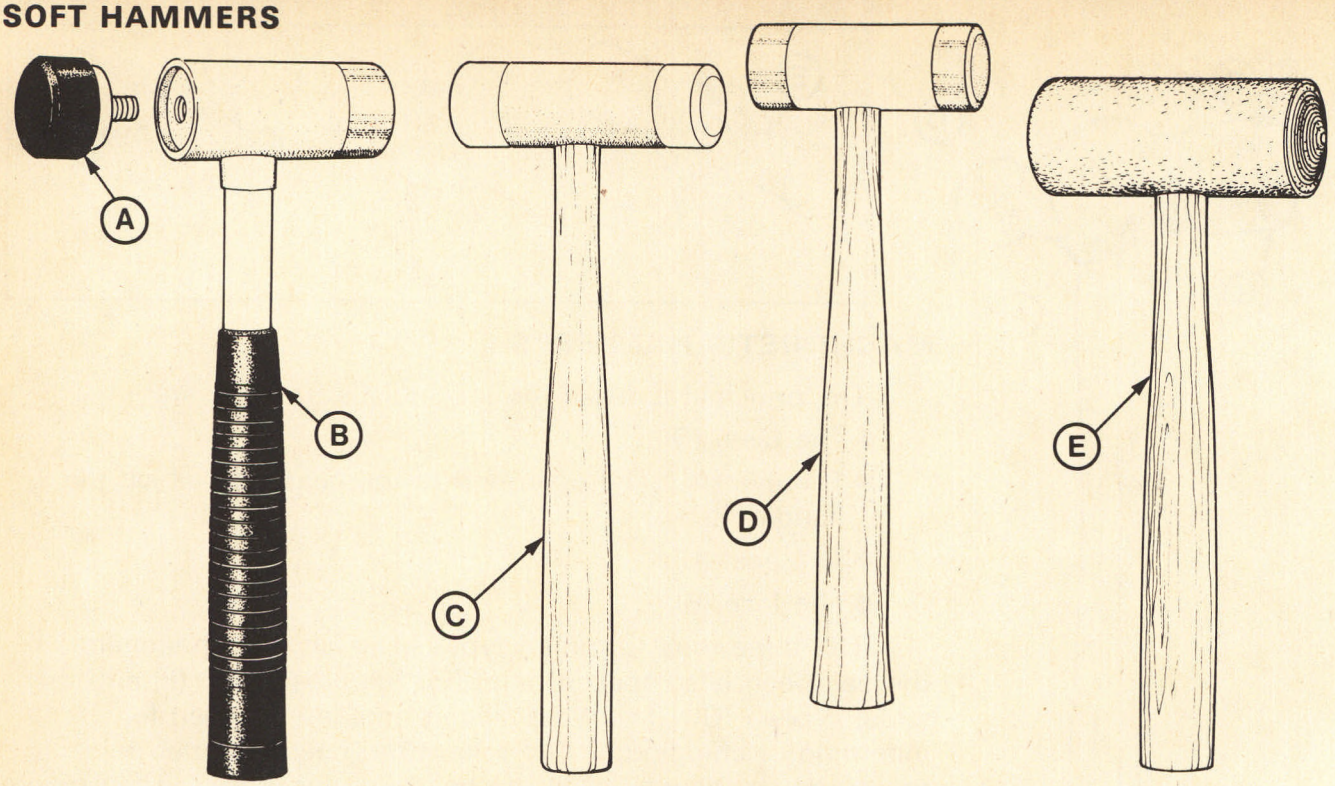
The cross-peen hammer (F) has a wedge-shaped peen that is horizontal to the hammer handle. The straight-peen hammer (G) has the same wedge-shaped peen, but it runs the same way as the handle. These hammer peens are used primarily for swaging (shaping cold metal) by striking it with successive blows. Many times a welder will use a cross-peen hammer to chip off excess weld slag (an ore residue eliminated from hot metals) while welding.





HAMMERS

SOFT HAMMERS



Soft hammers are used when it is necessary to strike an object which you do not wish to mar or damage. Most soft-face hammers have replaceable head tips (A), with the exception of the rolled rawhide mallet (E). The head tip centers are steel and threaded so they simply screw on and off the hammer head.

CAUTION

Do not strike hard metals with a plastic face hammer or damage to the hammer tips will result in the form of chipping, flaking or mushrooming.

The plastic tip hammer (C) is best suited for light hammering on small parts and will usually have a lightweight handle.

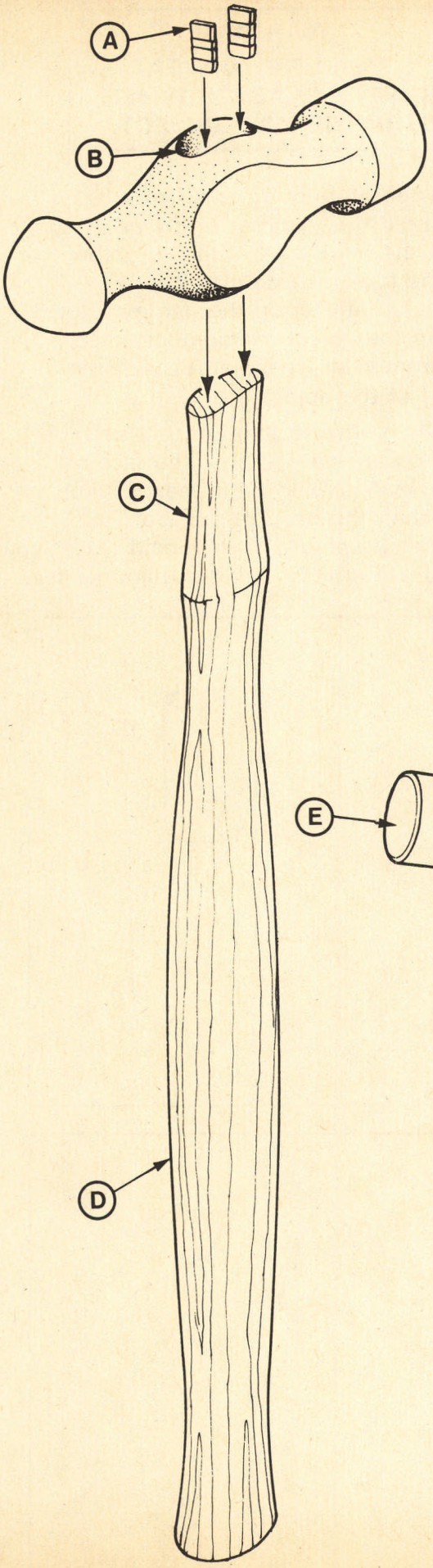
Hammer (B) is a dual-purpose hammer having two different grades (hardness) of head tips. Head tips are color coded for easy identification of their degree of hardness, which is indicated as follows:

- Neutral—made of nylon and very hard.
- Red—hard.
- Blue—medium.
- Green—soft.
- Gray—very soft.

The handle of hammer (B) is made of fiberglass with a non-slip rubber grip.

Brass tipped hammers (D) are used for striking a fairly heavy blow to steel parts without damaging the part. This is due to the "give" of the brass as the blow becomes stronger, thus protecting your steel part from damage. Brass-face hammers will not give off a spark, either, making them great for work in high fire danger areas (fuel tanks or systems, etc.).

The rawhide mallet (E) is just that, a rolled and treated piece of rawhide attached to a hickory handle. It's obvious that when striking a blow with the rawhide mallet, the rawhide will give before marring or breaking a piece of equipment.



HAMMER HANDLES

Most good hammer handles (D) are made of tough seasoned hickory, shaped to fit the hand and tapered at one end to give the hammer that certain ''spring'' when striking an object.

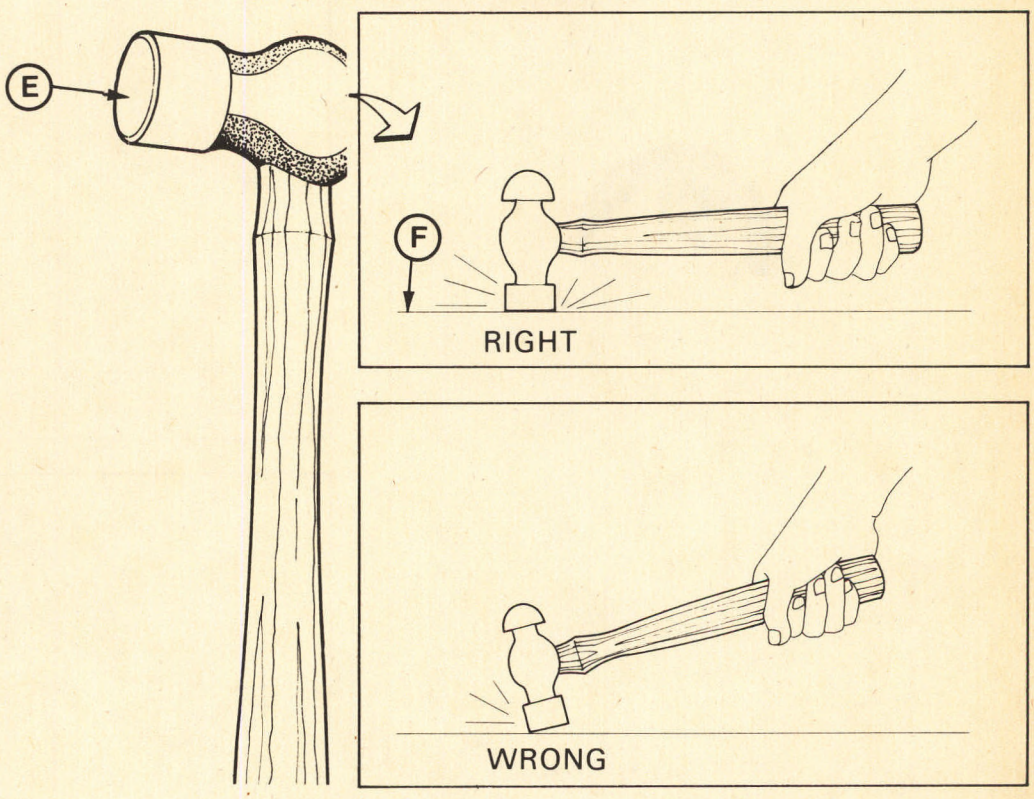
The eye (B) of the hammer head tapers from each end toward the center of the head, and the handle is formed in such a way to fit against the bottom taper, thereby preventing the head from slipping down the handle. The end (C) of the handle that extends into the top taper of the eye is expanded by driving one wooden wedge (A) or two metal wedges into the end of the handle to hold it in place.

WARNING

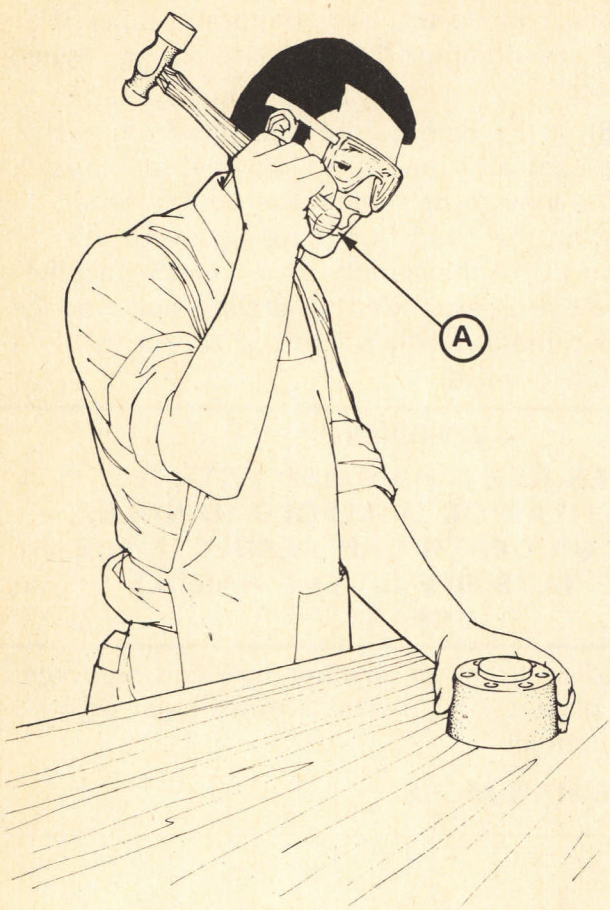
NEVER USE A HAMMER WITH A LOOSE HEAD OR DAMAGED HANDLE. INJURY OR DEATH CAN RESULT IF THE HEAD FLYS OFF OR THE HANDLE BREAKS.

Some handles are made of fiberglass and reinforced with polyester plastic. Also available are tubular or solid steel hammer handles.

HOW TO USE HAMMERS



When striking any object with a hammer, always strike the object squarely. In other words, be sure the hammer face (E) is parallel (F) with the object being struck. By properly striking an object, you will protect the hammer and prevent chipping or deforming the surface being struck.

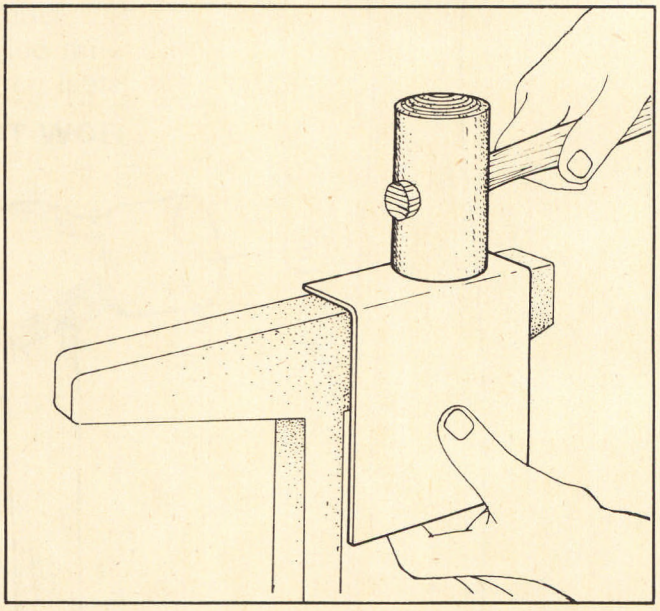


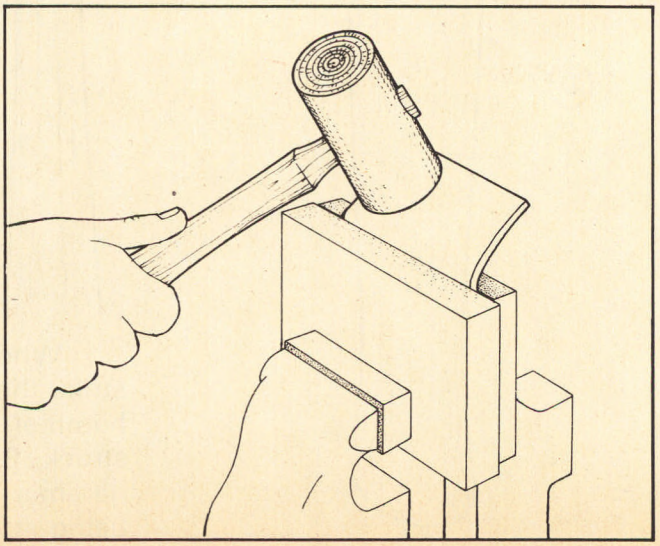
WARNING

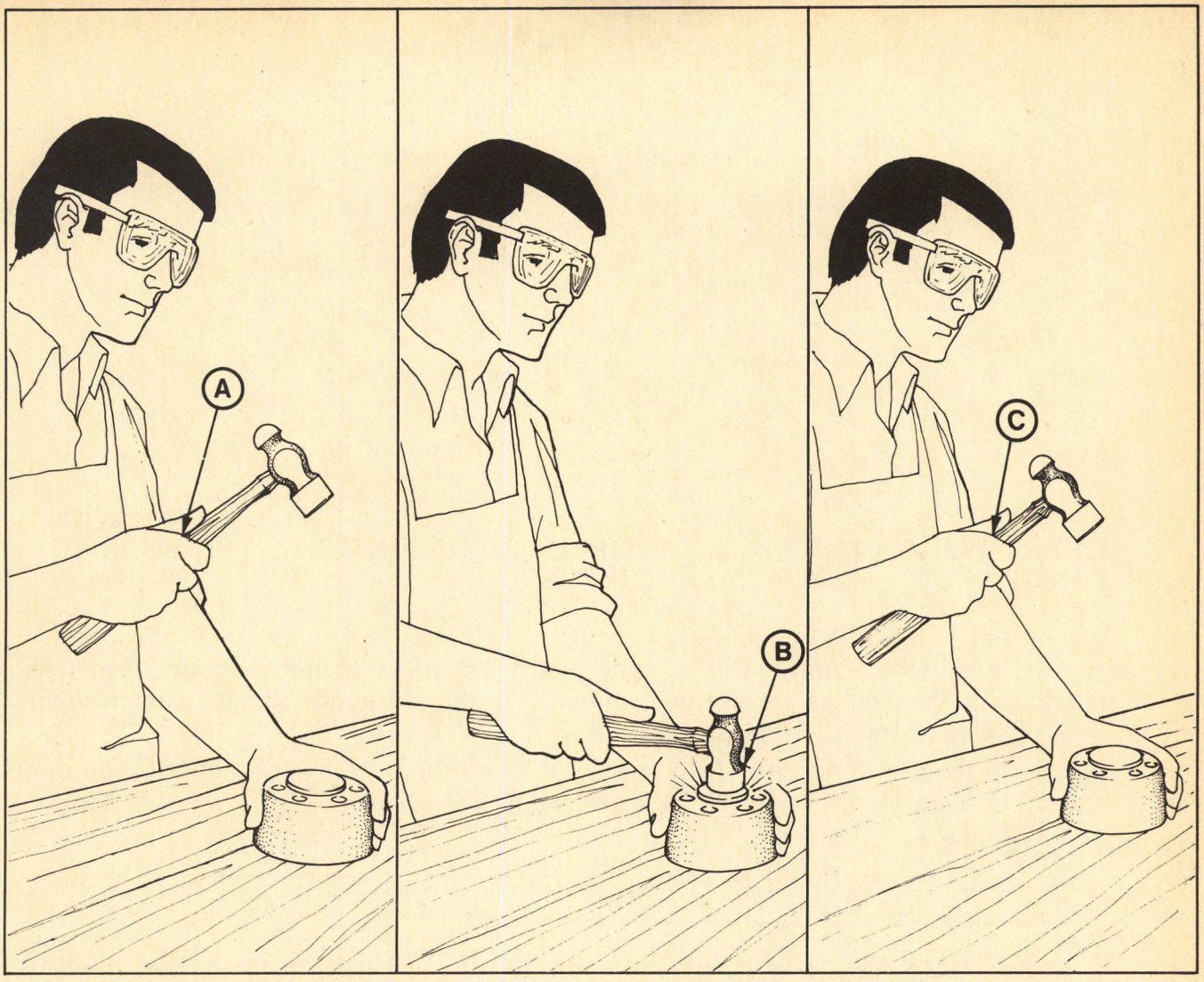
BE SURE TO WEAR SAFETY GLASSES WHEN STRIKING ANY OBJECT.

When attempting to strike a heavy blow, hold the hammer firmly near the end of the handle (A). Start the blow with the forearm extended nearly straight up and bring the hammer down hard on the object. Remember, keep the hammer face parallel (B) with the surface of the object.

When striking another tool such as a cold chisel, punch, etc., the face of the hammer should be at least ½-inch larger than the head of the tool. Example: If using a ½-inch cold chisel, you should use at least a 1-inch hammer face.







To strike a light blow, grasp the hammer handle further up nearer the center (A) and raise the hammer a shorter distance to obtain the desired striking force. Again, be sure the hammer comes down on the object squarely (B). Quite often in striking a light blow, only wrist action is needed, requiring little movement of the arms.

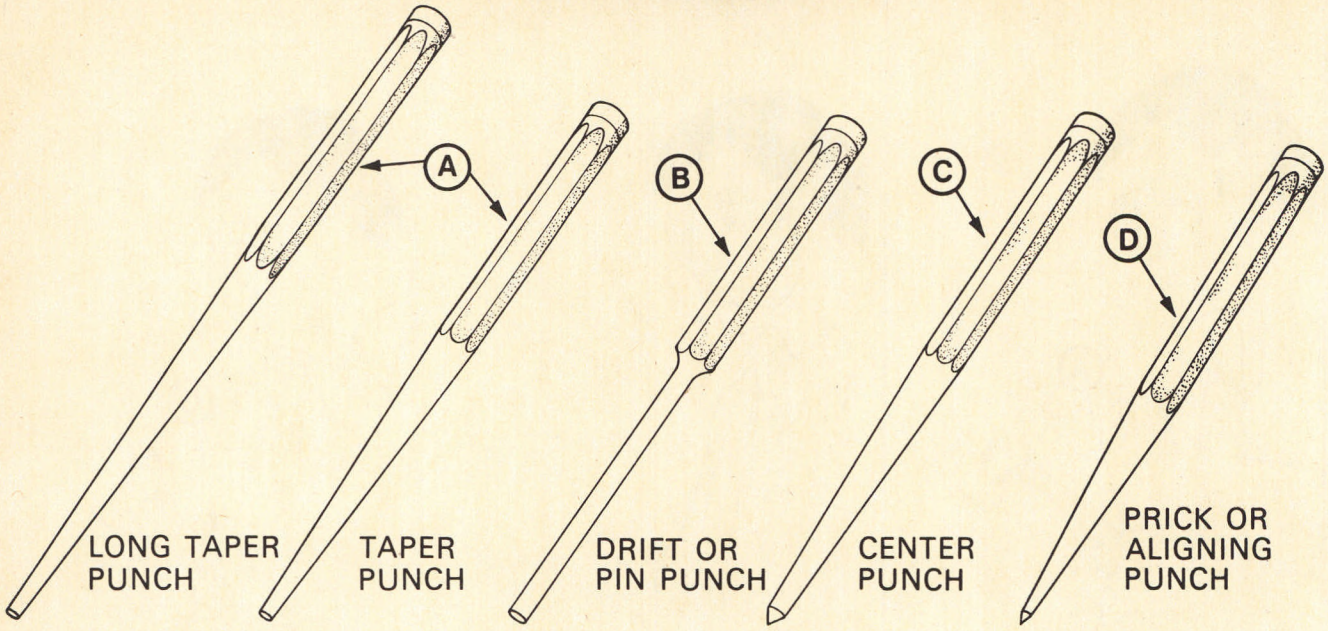
Never grasp the hammer handle too near the head (C). In doing so, the hammer head will surely strike the object at the wrong angle.

CARE OF HAMMERS

The following are tips in caring for your hammer as well as safety points to *always* remember:

- Keep your hammer clean at all times.
- *Always* wear safety glasses when striking any object.
- *Never* use a hammer with a damaged head or broken handle.
- *Never* strike hard metals with a soft-face hammer.
- *Always* be sure the hammer face strikes the object squarely.
- Know your hammer sizes and soft-face color codes.
- *Always* purchase a brand name hammer for your safety.
- *Always* use a hammer of the correct size and weight for the job. Example: Don't use a tack hammer to drive a spike, nor a sledge hammer to drive a tack.
- *Never* strike an object with the side of a hammer.
- There is a right way and a wrong way to use a hammer. Learn to use it the right way.

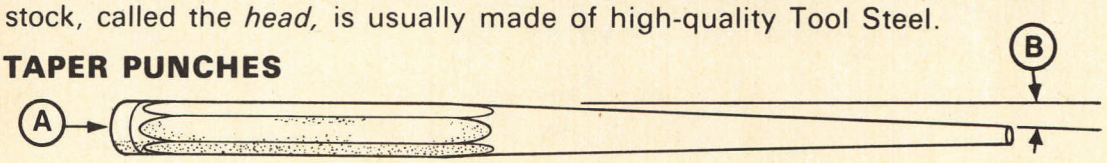
PUNCHES



Punches are used for a variety of jobs, and there is a size and shape to fit any need. The most commonly used punches are the taper punch (A), the pin punch (B), the center punch (C) and the prick or aligning punch (D).

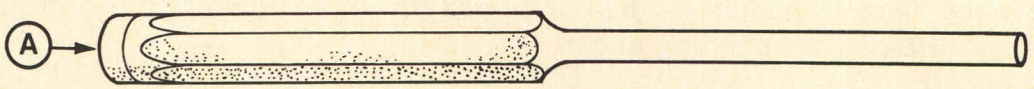
The highly-polished, ground end of the punch is called the *bit.* The remainder of the punch stock, called the *head,* is usually made of high-quality Tool Steel.

TAPER PUNCHES



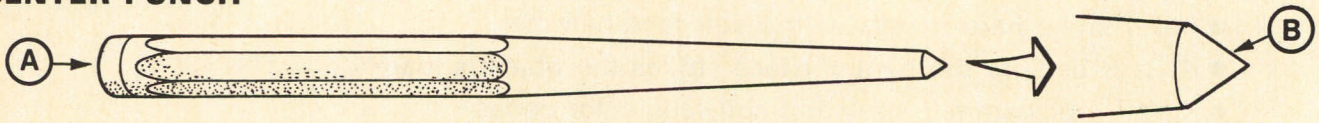
The taper punch (A) has a very long, tapered bit (B) and a flat point. (They vary in overall length from six inches up to 14 inches.) Taper punches are not used primarily as a punch, but more for aligning holes in several pieces of metal (such as a fender to the body, etc.) through which a bolt or screw is to be inserted.

DRIFT OR PIN PUNCH



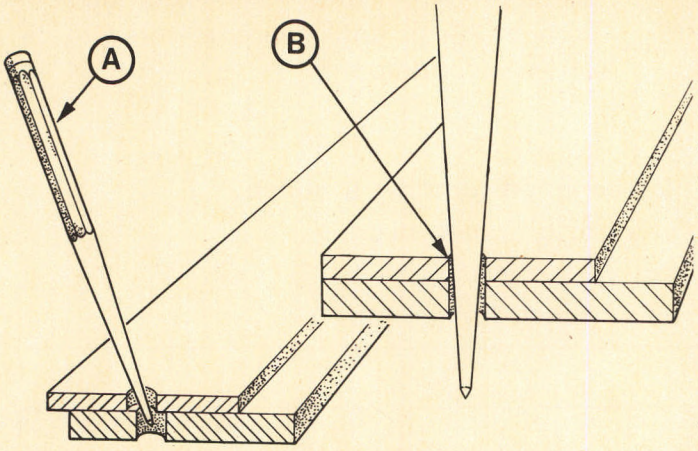
The drift or pin punch (A) is used to drive out tapered and straight pins from holes into which they have been forced. The diameter of the punch is the same from point to body. That way, as the punch is driven into the hole to remove the pin, it will not distort or enlarge the hole—provided you have chosen the correct diameter punch, which should be just slightly less than the diameter of the hole.

CENTER PUNCH



The center punch (A) has a tapered bit (B) with a broad, sharp point. It is used primarily for punching an indentation in a piece of metal as a guide for starting a drill bit. Example: Mark the part to be drilled with a scribe (metal scratching tool) or pencil, then place the center punch directly on this mark. Using a hammer, strike the head of the punch a good sharp blow. The indention in the material will prevent the tip of the drill from slipping out of position, thus making it easier to start your drill.

PRICK OR ALIGNING PUNCH

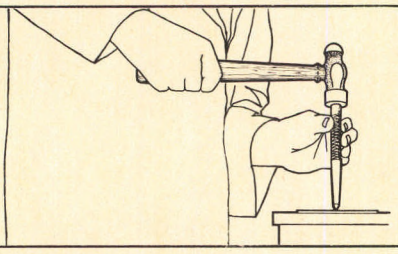


The prick or aligning punch (A) has a bit that is tapered from the body to a very narrow, sharp point. This punch is used to produce very small indentations (unlike the center punch) on the surface of metal to act as guide lines or reference points prior to some other layout operation. It is also used to align holes (B) in several pieces of metal by shoving it into the holes and then working the punch back and forth until it is vertical. As the punch is moved back and forth, it works deeper into the hole; the pieces of material shift and the holes are aligned.

CAUTION

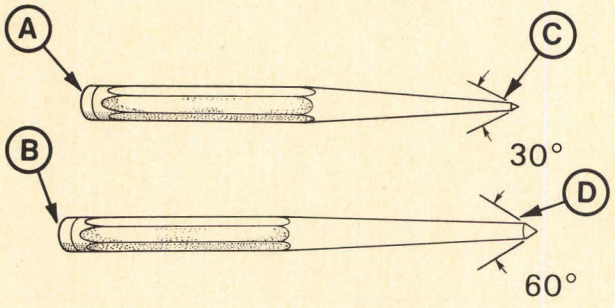
Be careful not to apply too much pressure to the prick punch end when attempting to align material or damage to the punch could result.

HOW TO USE THE PUNCH



The prime thing to remember in using a punch and hammer is to strike the punch squarely. A glancing blow could damage the material you are working on or injure your fingers badly. Also, never use the side of the hammer head to strike a punch.

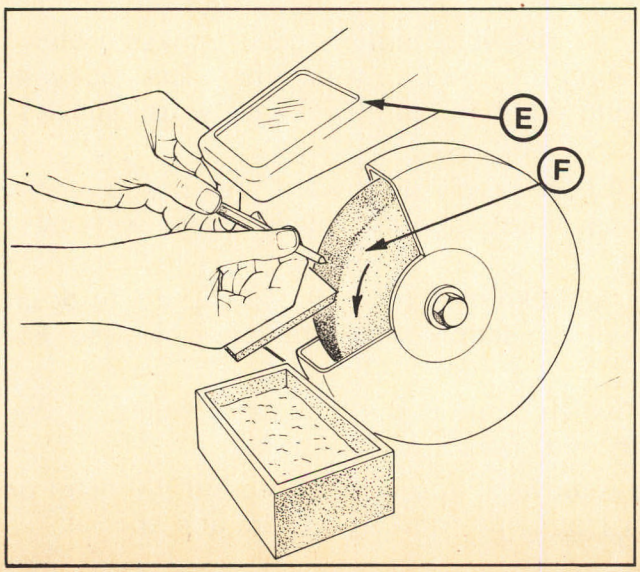
CARE OF PUNCHES



The points of prick (A) and center (B) punches will become dulled in time. When this happens they can be restored with a grinding wheel (F).

WARNING

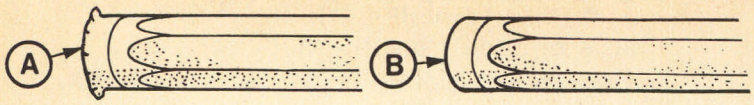
ALWAYS WEAR SAFETY GLASSES WHEN USING THE GRINDER FOR ANY REASON. BE SURE THE SAFETY SEE-THROUGH GUARD (E) ON THE GRINDER IS POSITIONED OVER THE WORK.



The prick punch should be ground to a 30° bevel (C) and the center punch ground to a 60° bevel (D).

When grinding punches, do not apply too much pressure against the wheel. Continuously rotate the punch as long as it is against the wheel until the desired bevel (angle) is obtained. To hold the punch too long against the grinding wheel will cause the punch to get too hot, turning it blue. Overheating will draw (remove) the temper (hardness) from the point, making it soft and useless. Remove the punch from the grinding wheel at frequent intervals and quench (dip) it in cool water. The water will quickly cool the point.

PUNCHES

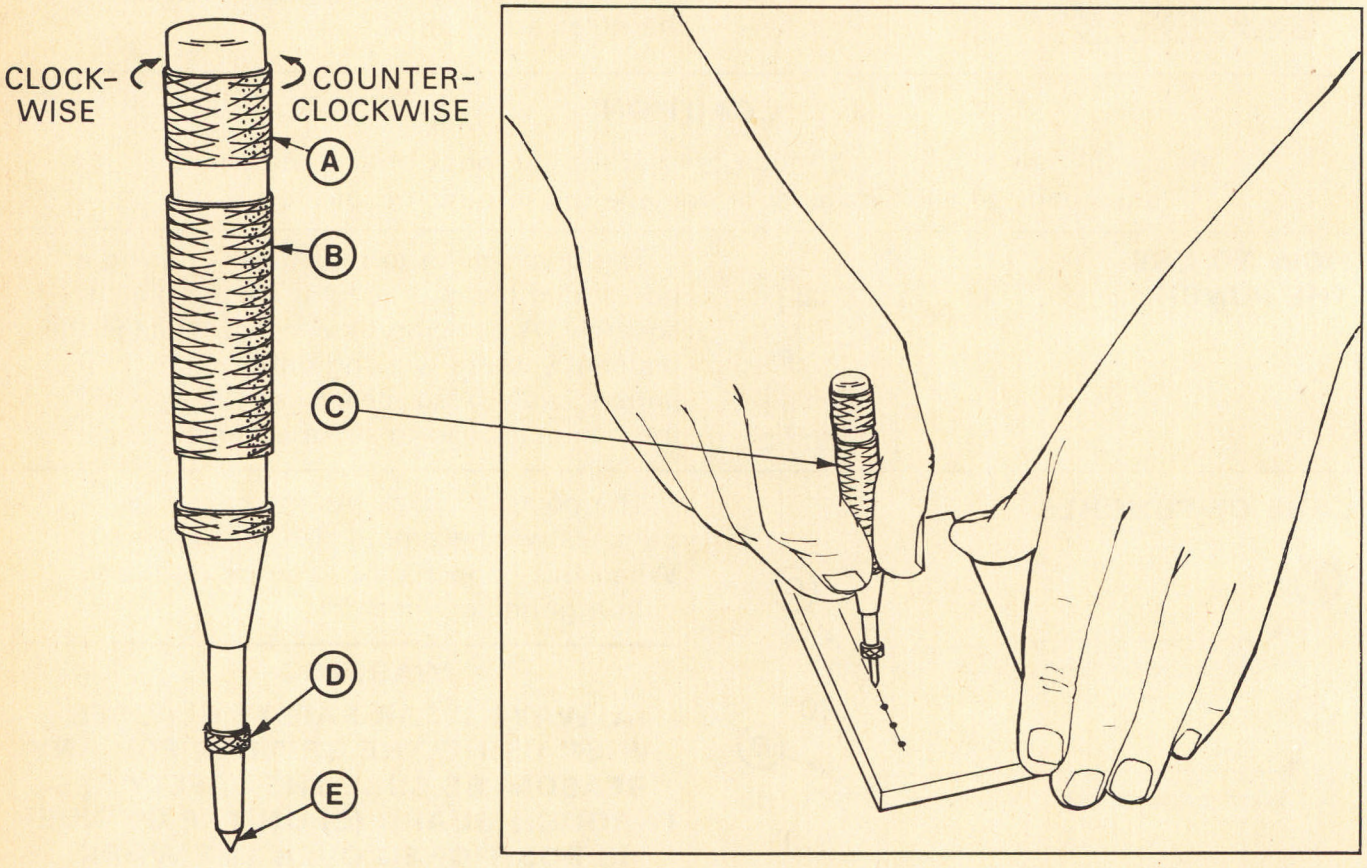


If the head of the punch becomes damaged or mushroomed (A), grind it smooth (B) or until nearly restored to its original condition.

Remember:

- Always wear your safety glasses when grinding a punch.
- Never use a punch that has a mushroomed head.
- Never carry a sharp punch in your pocket.
- Use the correct size and shape punch for the job.

AUTOMATIC CENTER PUNCH



The automatic center punch (B) is one of the greatest advances in the design of tools that make your job easier. This punch contains a mechanism which automatically strikes a blow when downward pressure is applied, thus eliminating the need for a hammer. This tool will allow you to perform more accurate work by freeing one hand and will save your knuckles from getting hit with the hammer.

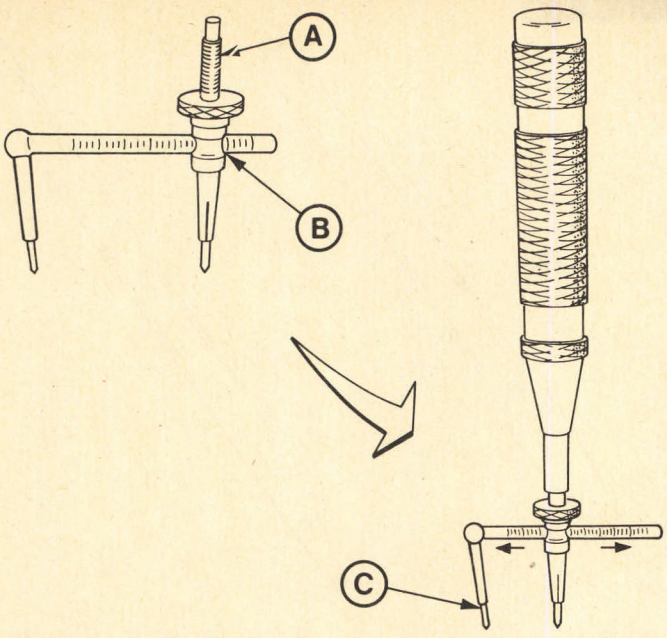
Simply hold the punch in the upright position (C) and apply downward pressure to release the internal striking block. You now have the proper impression accurately placed without slipping.

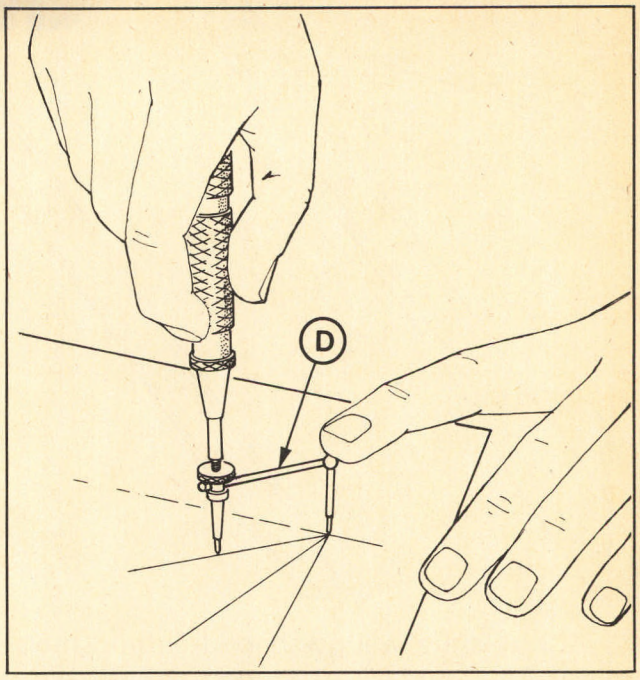
The force of the blow is controlled by the adjustable knurled (ridged) cap (A). If you desire a heavy blow to the piece of material being worked on, simply rotate the cap clockwise. For a lighter blow, turn it counterclockwise.

The tension on the internal spring mechanism which controls the blow is constant, so the marks made by the point (E) are uniform in depth and size for each setting.

The point is threaded and knurled (D) for easy removal if you wish to regrind the point or install a new one. Special points are available for stamping numbers, letters and special symbols.

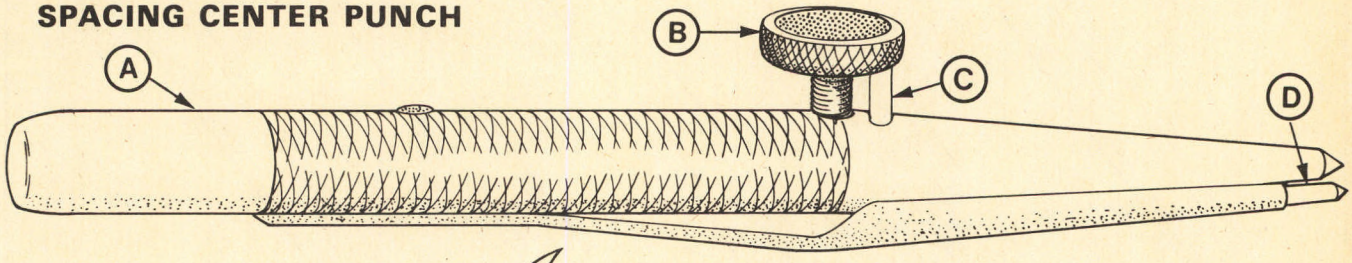
SPACING ATTACHMENT FOR AUTOMATIC CENTER PUNCHES

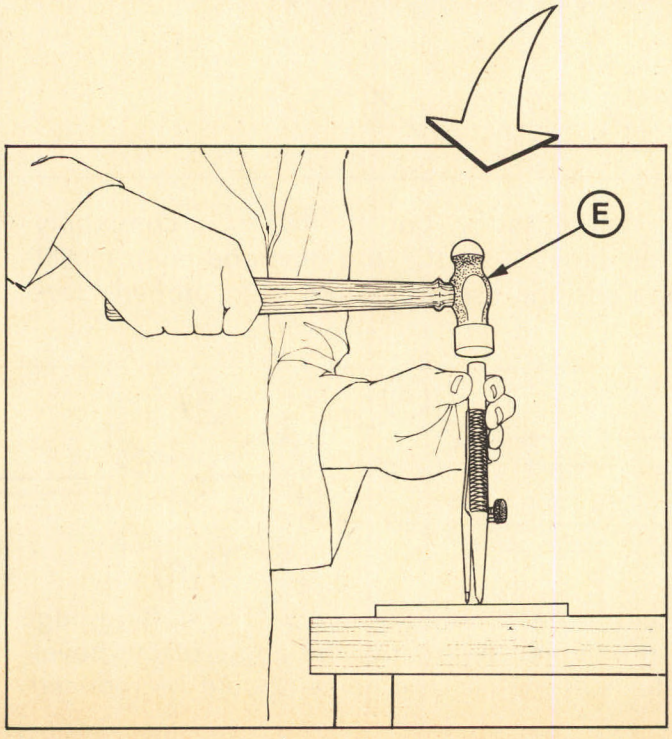




The spacing attachment (B) is used for accurately spacing center distances (D). It is commonly used where numerous exactly-shaped indentations are needed. The attachment is threaded (A), and it screws right onto the center punch in place of the original point. The locating point (C) is frictionally held and is easily adjusted and placed. Depending on the model of center punch, the locating point can be adjusted from 1/16-inch up to 1¾ inches.

SPACING CENTER PUNCH

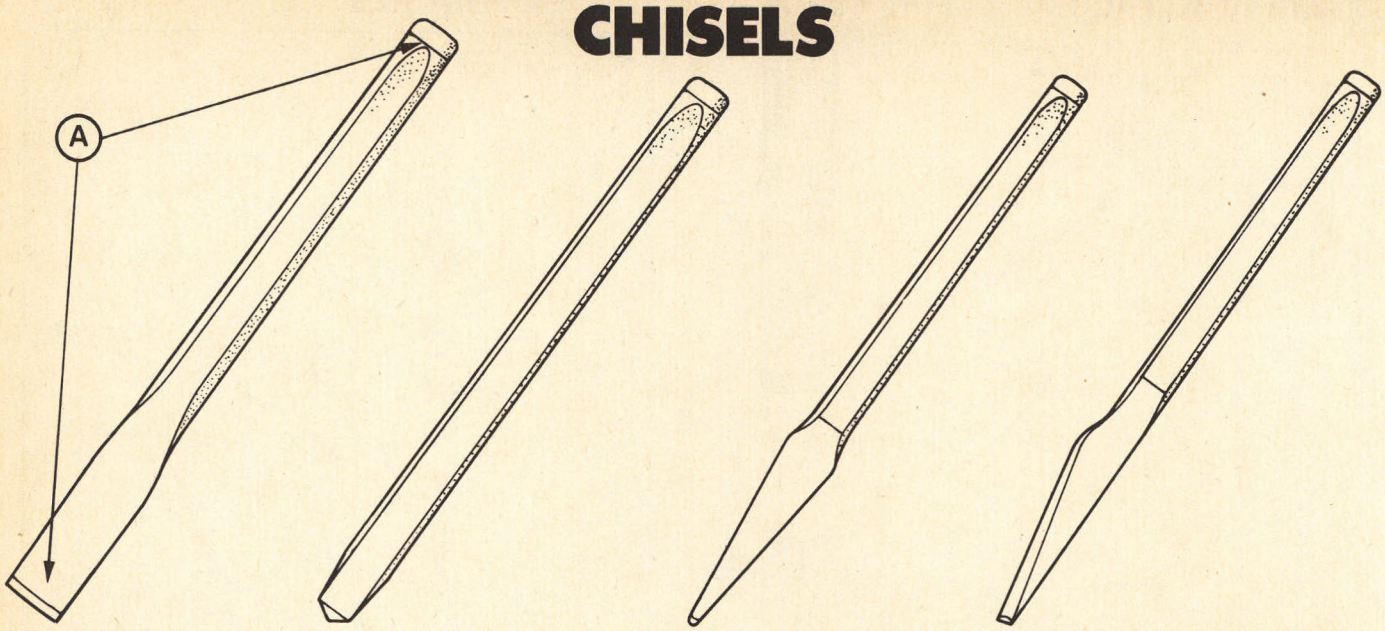




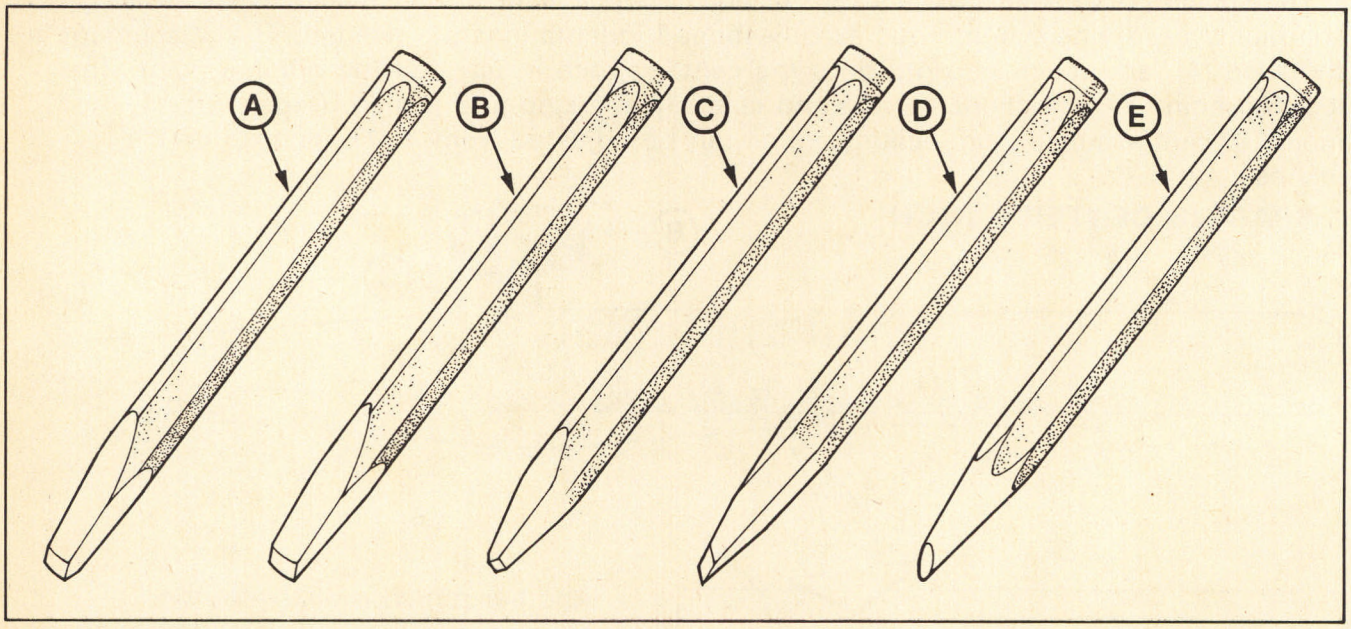
Another punch available is the combination center punch and spacing tool (A). This is not automatic, but it will permit you to accurately space center distances for drilling, using a hammer.

The guide point (D) is set in a socket and a spiral spring holds it in position. When the punch is struck with a hammer (E), the guide point is forced into the socket against spring pressure. This feature permits the punch to be held upright to the work, assuring accurate spacing. A knurled screw (B), when adjusted, works against a pin plunger (C) and adjusts the spring arm that holds the guide point in position. The spacing adjustment ranges from 5/64-inch up to 3/8-inch.

CHISELS

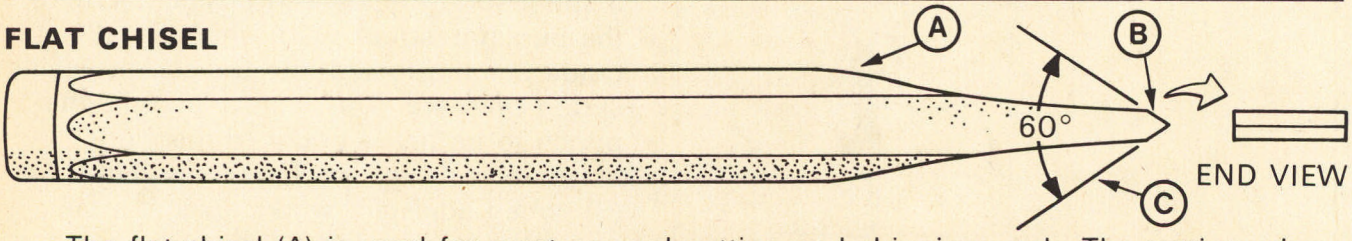


Chisels are wedge-shaped cutting tools used primarily for cutting, shearing and chipping metal. The ends (A) of a good chisel have been heat treated for extra hardness and durability.



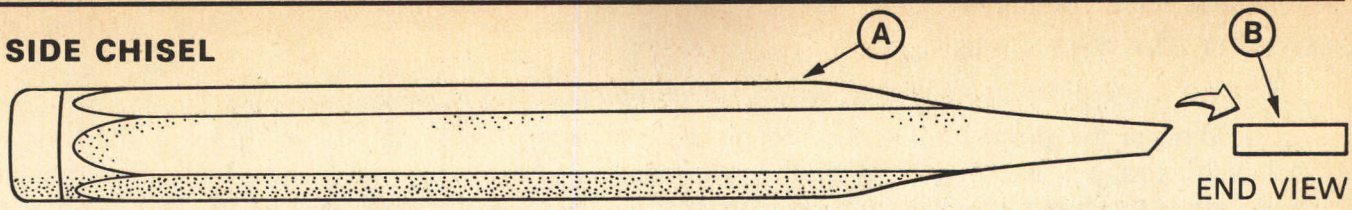
There are many different chisel sizes on the market today, but the five most commonly used are the flat chisel (A), the side chisel (B), the cape chisel (C), the diamond-point chisel (D) and the round-nose chisel (E). Each one has a specific use and when used properly will perform different cutting functions.

FLAT CHISEL



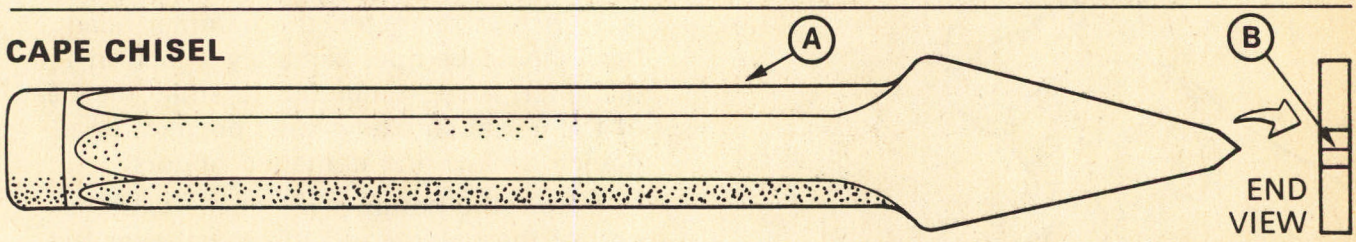
The flat chisel (A) is used for most general cutting and chipping work. The cutting edge (B) is beveled (tapered) from both sides toward the center. Normally, the angle of the bevel should be between 60° and 70° (C). However for soft metals, the angle should be reduced and for very hard metals, increased.

SIDE CHISEL



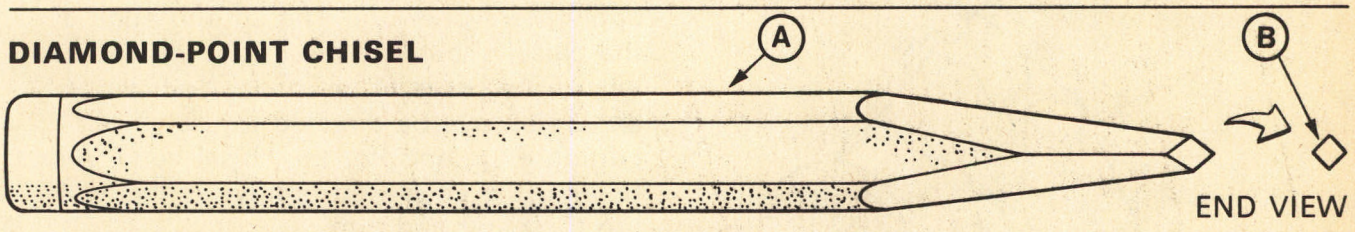
The side chisel (A) is very similar to the flat chisel, but differs in that its point (B) is beveled (tapered) to one side only. This permits it to be used on surfaces which could not be reached by the edge of the flat chisel. This chisel is very handy for chipping in slots and grooves, such as pulley keyways, etc.

CAPE CHISEL



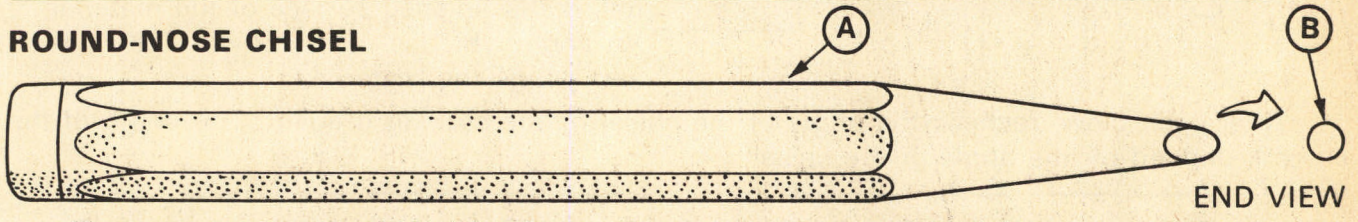
The cape chisel (A) has a very narrow cutting point (B), unlike the flat chisel or the side chisel. This chisel is used primarily for cutting narrow grooves in metal.

DIAMOND-POINT CHISEL



The diamond-point chisel (A) gets its name from the fact that its point (B) is ground to a shape like a diamond. This shape allows you to chip V-grooves or clean out square corners of metal.

ROUND-NOSE CHISEL



The round-nose chisel (A) (also known as the round-point chisel) has a round cutting edge (B) as its name indicates. It is used for cutting grooves in metal where an oval shape is desired.

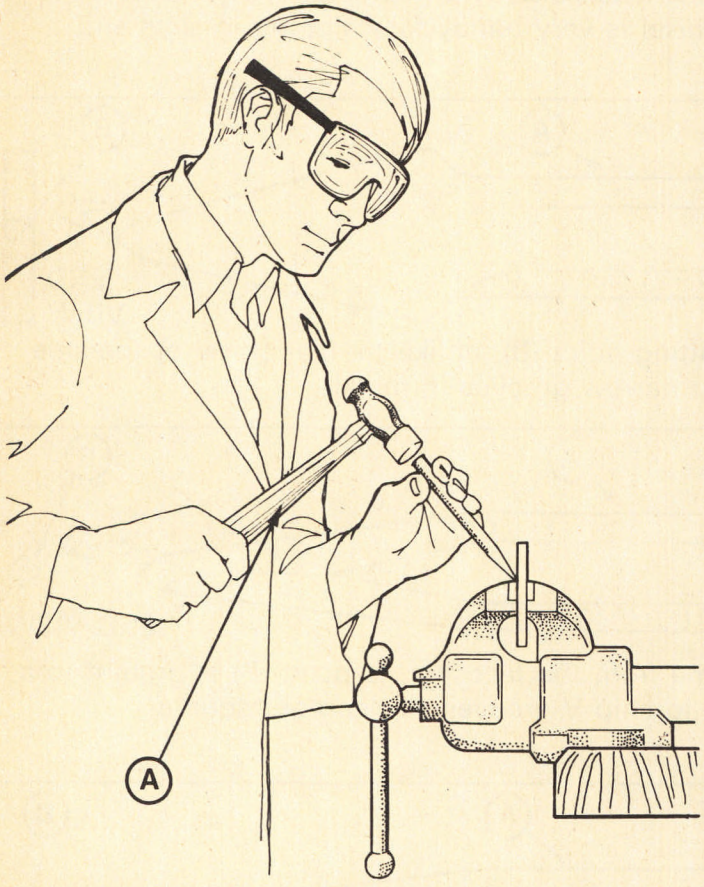
Chisels come in different shapes, but most often they will be octagon shaped for better control of the chisel. The number on the side of the chisel (if any) will usually be the manufacturer's code number or catalog number, and not the size of the chisel. Chisels are measured for size by their length, diameter and width of cutting edge. All dimensions are expressed in inches.

WARNING
ALWAYS WEAR SAFETY GLASSES WHEN USING A HAMMER AND CHISEL.
NEVER USE A CHISEL WITH A BATTERED (MUSHROOMED) HEAD. STEEL FRAGMENTS COULD FLY OFF THE HEAD, CAUSING SEVERE INJURY TO YOURSELF AS WELL AS OTHERS NEARBY.

HOW TO USE THE CHISEL

Chisels are mainly used in two ways, for *chipping* and *shearing.*

Chipping is the process of removing pieces of metal from material, using a hammer and chisel. With today's many modern methods of removing excess metal (rotary files, pneumatic chisels, etc.), the hand chisel is not used that often. However, it is a very good idea to be familiar with the procedure and its use in case you have an occasion to use it.

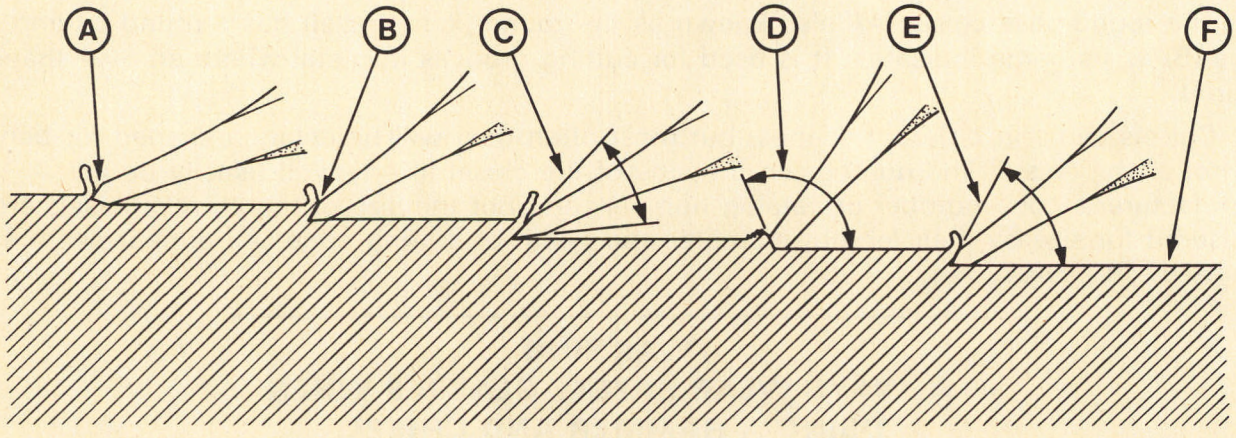


First, remember that the diameter of the chisel should be approximately ½ that of the hammer's face. Example: If your chisel is ½-inch in diameter, the hammer head face should be approximately 1 inch in diameter. Also, remember to strike the head of the chisel squarely, thus preventing a glancing blow and damaged fingers.

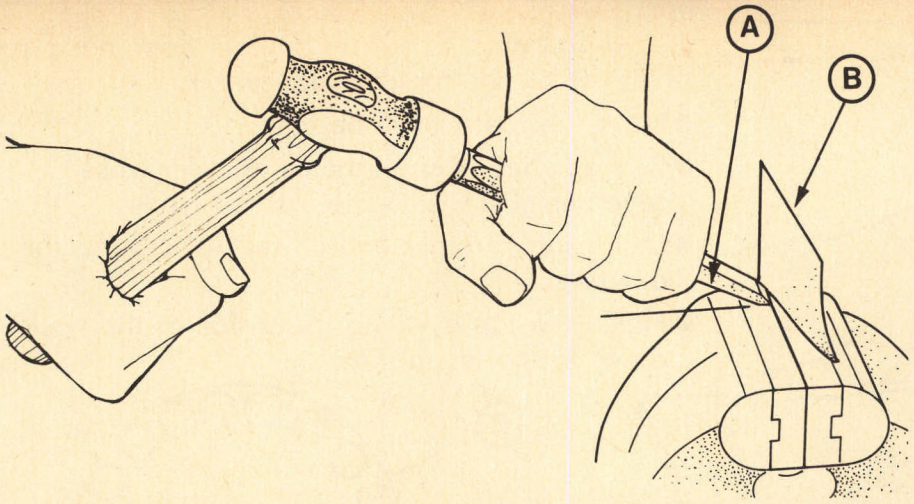
Hold the hammer (A) at the extreme end of the handle and the chisel near the head. The thumb and first finger should lightly hold the chisel while the other fingers apply more pressure. The cutting edge of the chisel should be held right on the area where the cut is to be made. Your vision should always be directed to the chisel cutting edge and *not* the chisel head. Avoid holding the chisel too tightly, as this will tire the hand and arm.

Be sure the angle of the cutting edge to the material being cut is correct. The *correct* angle will cause the chisel cutting edge to follow the finished surface of the material. An angle which is *incorrect* will "bite" in and gouge the material.

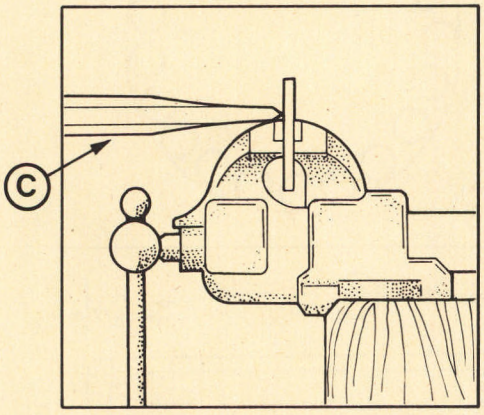
After each blow, recheck the angle of the chisel before striking it again. The depth of the cut will depend on the angle of the chisel.

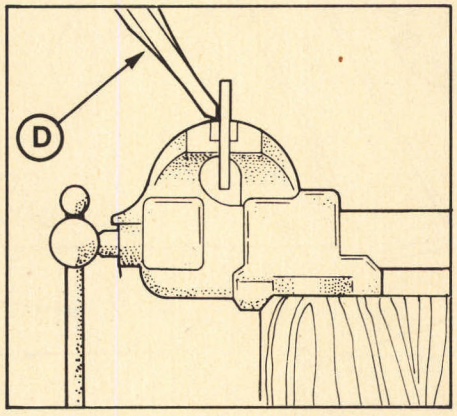


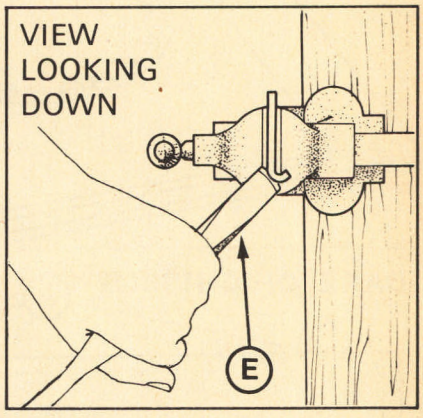
As each blow is struck, the chisel should tend to move along the supporting surface (F) (the vise jaws or another piece of metal, etc.). Lowering the chisel head will cause the cutting edge (A) to move up and raising the chisel head will cause the cutting edge (B) to move down and dig deeper into the material. The angle of the cutting edge (C) is too narrow for chipping; it is very weak and can easily be broken. The angle of the cutting edge (D) is too blunt and tends to *push* the metal rather than *cut* it. The cutting edge angle (E) is best for general all-around chipping and should be approximately 60° to 70°.



When shearing with a hammer and chisel, the material (B) should be held in the upright position in a vise. The chisel should be held tightly near the head with the cutting edge of the chisel parallel (A) (approximately 30°) with the jaws of the vise. The chisel and the vise jaw together will act as a shear, making a smooth cut.

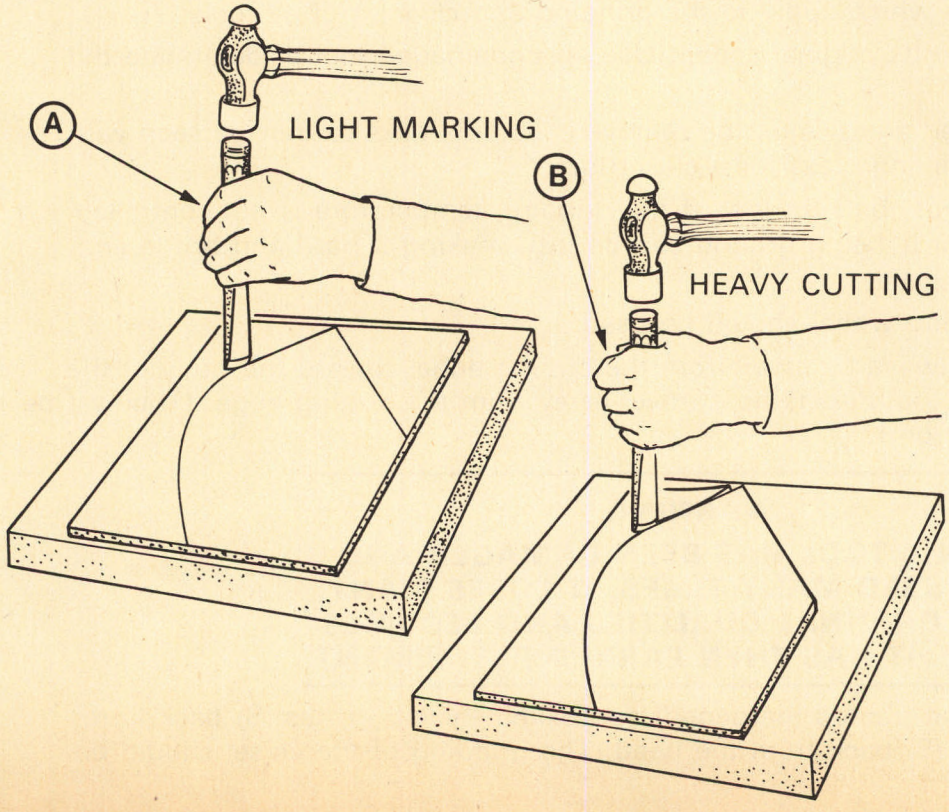






The shearing action will be lost if the head of the chisel is held too low (C). The material will be bent or torn rather than sheared off. If the chisel head is held too high (D), you will drive the chisel into the vise, damaging the chisel.

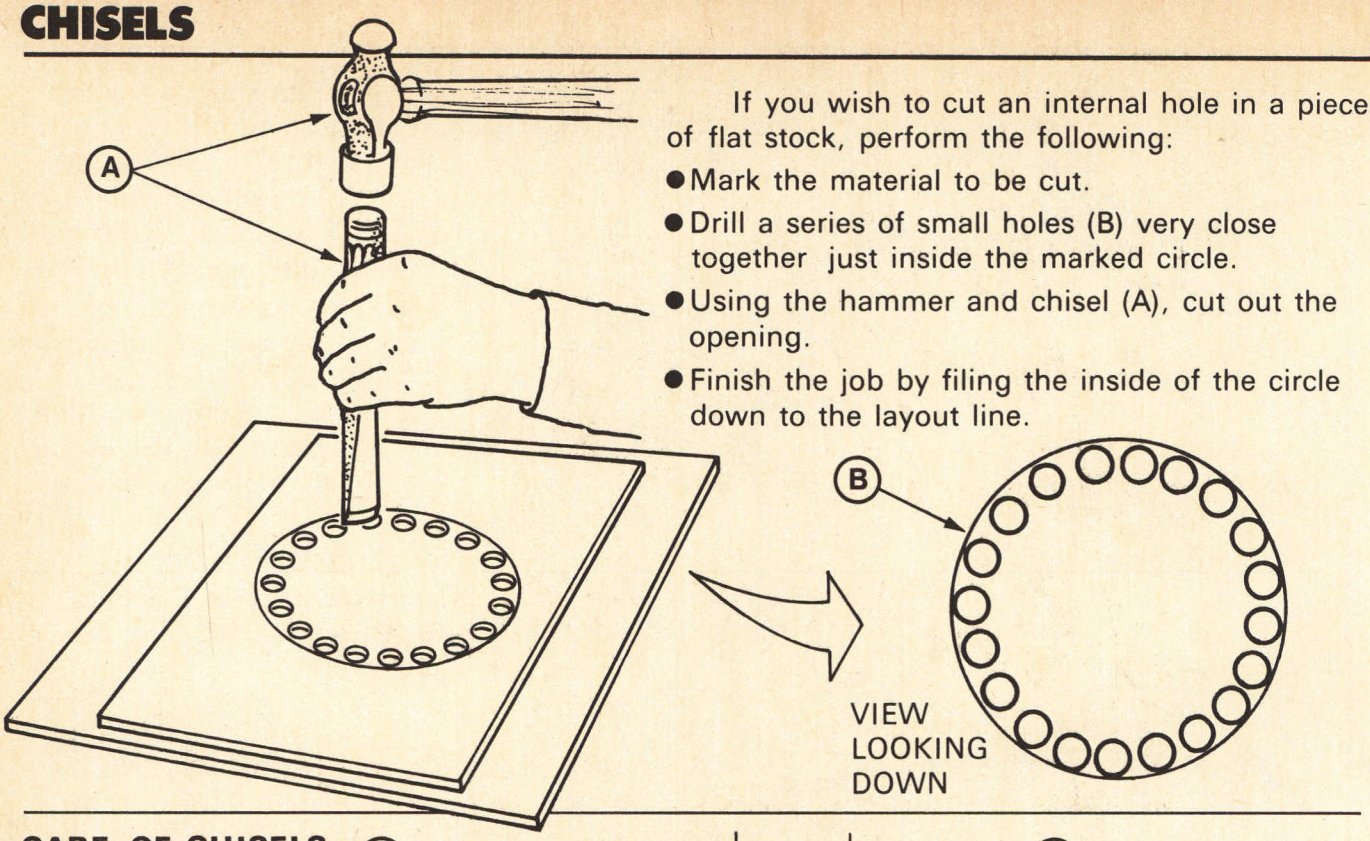
Another method of shearing is to place the chisel at an angle (E) to the vise, which will give you that ''slicing'' action needed for fast, easy removal of material.



When attempting to cut a flat piece of material, observe the following steps:

- Place the material flat on a soft metal plate. Never use a hard surface for cutting or damage to the chisel will result.
- Put your safety glasses on.
- Hold the chisel firmly. (Note the different hand grips for marking [A] and cutting [B].)
- Using the punch and hammer, lightly mark (A) the layout line on the material. Keep your eye on that cutting edge, not the chisel head.
- Strike heavy cutting blows (B) to the indented outline on the material.

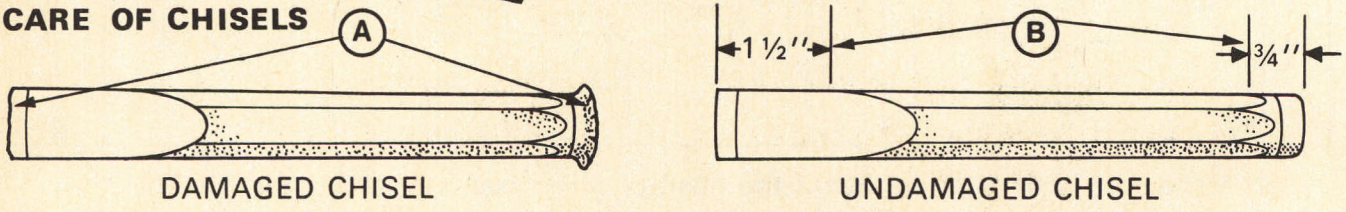
CHISELS



If you wish to cut an internal hole in a piece of flat stock, perform the following:

- Mark the material to be cut.
- Drill a series of small holes (B) very close together just inside the marked circle.
- Using the hammer and chisel (A), cut out the opening.
- Finish the job by filing the inside of the circle down to the layout line.

CARE OF CHISELS



DAMAGED CHISEL

UNDAMAGED CHISEL

When a chisel becomes worn or damaged (A) it must be dressed (cleaned up or repaired) before using it again. Damage to a chisel usually occurs in two areas, the head and the cutting edge. The head will mushroom with prolonged use and the cutting edge will become nicked and dull.

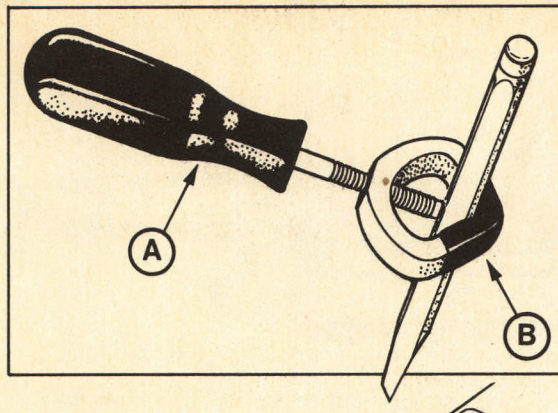
There are five basic rules which apply to the grinding and cleanup of all tools:

- The tool must be returned to its original shape. Use an undamaged tool to determine the original shape.
- All cracks and spalls (chipped areas) must be removed. Some cracks cannot be seen with the naked eye. Use a magnifying glass for a closer look.
- The grinding temperature must be kept low. If the grinding temperature is not controlled, the hardness of the area that is being ground can be lost, making it hard and brittle and easily fractured when used again.
- A medium or fine grit grinding wheel should be used.
- The wheel rotation should always be *away* from the cutting edge, toward the body of the tool. This positioning of the tool directs heat travel away from the cutting edge. (This will be shown in greater detail later on.)

WARNING

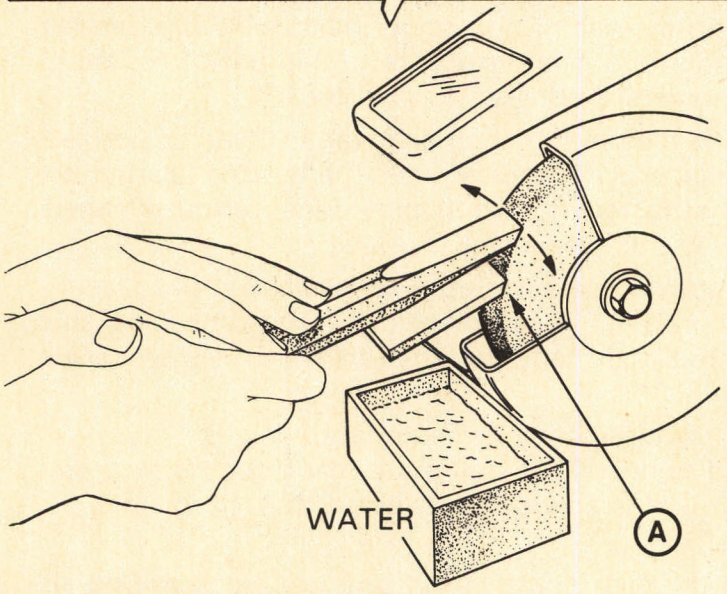
WHEN A TOOL HAS BEEN DAMAGED AND REDRESSED MANY TIMES, IT LOSES MANY OF ITS ORIGINAL QUALITIES AND BECOMES UNSAFE. IT HAS THEN EARNED RETIREMENT.

Generally, chisels are heat treated (hardened) approximately 1½ inches (B) back from the cutting edge and ¾-inch (B) back from the head. The grinding of the chisel should be kept well within these areas.



HANDY HINTS

There is a very handy chisel and punch holder (A) available on the market today which will save your knuckles when attempting to do this kind of work. Simply place the tool in the holder at the proper angle and tighten the handle of the holder. The heavy plastic coating (B) assures a firm grip. You now have a way to safely strike the chisel or punch.

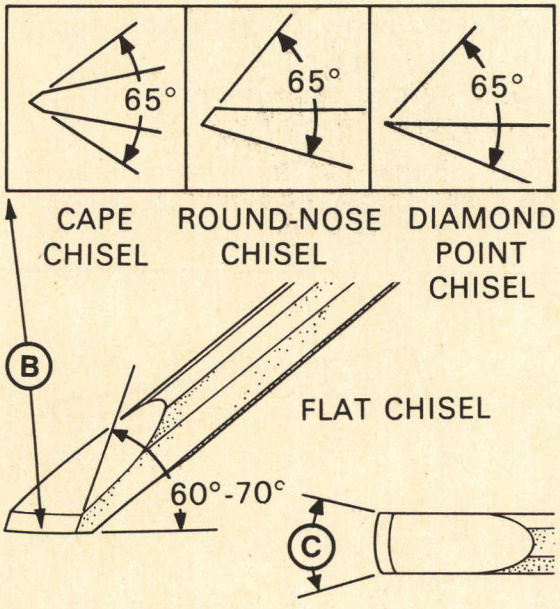


WARNING
ALWAYS WEAR SAFETY GLASSES WHEN USING THE GRINDER FOR ANY REASON. BE SURE THE SAFETY SEE-THROUGH GUARD ON THE GRINDER IS POSITIONED OVER THE WORK.

The correct bevel (B) on a chisel may vary from an angle of 55° to 90°, depending upon the material you wish to cut. For general all-around use, however, 60° to 70° is best.

When grinding, there should also be a slight curve (C) to the width of the flat chisel as well as the correct bevel.

When using the grinding wheel (A), the chisel should be held at the desired angle and moved across the face of the wheel. Grind one side and then the other to form a sharp edge. The pressure applied to the chisel against the wheel should not be great enough to overheat the chisel end and draw (remove) the temper from the chisel. If the temperature of the chisel end rises to a point where the metal turns blue in color, the temper has been lost and the end softened so it will no longer stand up to normal use. A tool that has been incorrectly dressed like this will have to be re-heat treated to restore the temper. (Heat treating is a special process and is covered in many engineering books available on the market.) Frequently dip the chisel end in water when grinding to keep the metal cool and to prevent overheating.



REMEMBER:

- Always wear your safety glasses when using the hammer and chisel or when grinding a chisel.
- Never use a chisel that is dull or mushroomed.
- Never carry a sharp chisel in your pocket.
- Never use a metal cutting chisel to split stone or concrete.
- Use the correct size and shape chisel for the job.

MOTO-TOOLS

This book has been devoted to instruction in the use of non-power hand tools, but we felt that the electrically-powered Moto-Tool (A) should be given exposure in this book because of the many valuable uses that the novice mechanic or hobbyist can find for it.

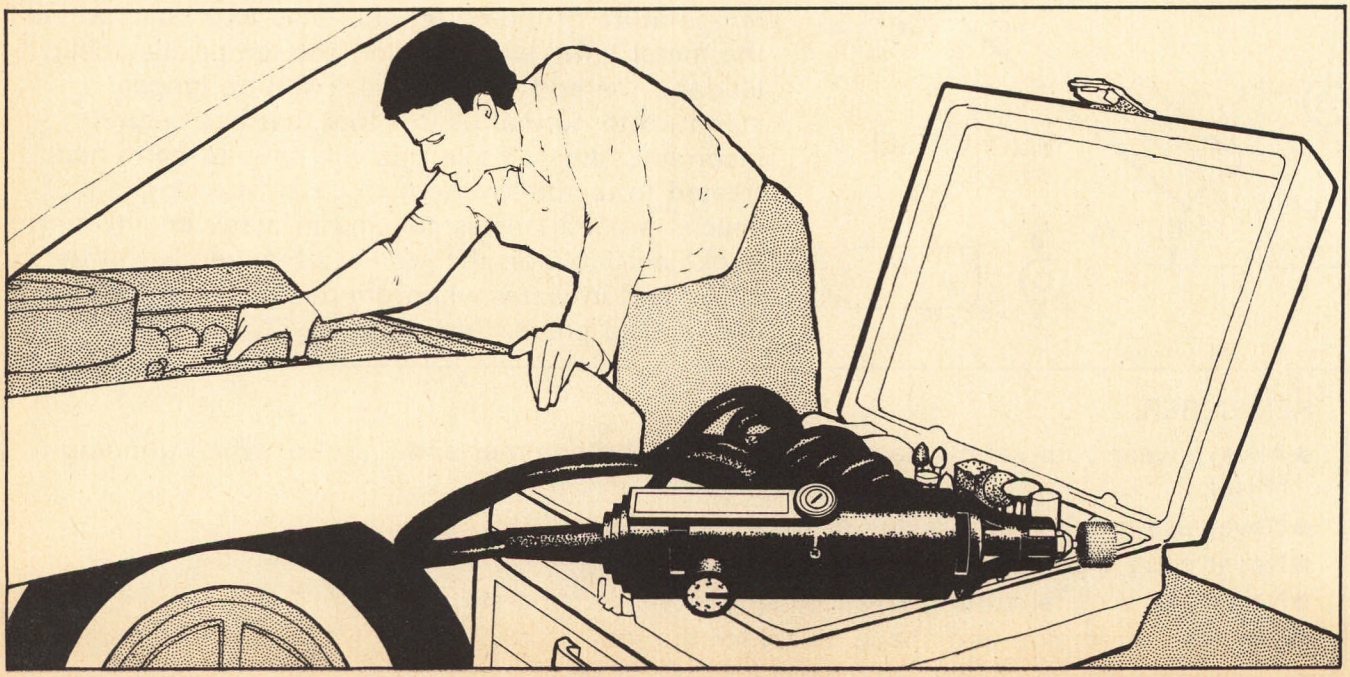
This tool will quickly do a thousand and one jobs in the shop or garage. It will cut cables and frozen hose clamps, remove rust from engine parts, radius intake parts, clean carburetor jets, enlarge holes, cut tubing, clean threads of fasteners, deburr pipe ends, reslot damaged screws, remove excess solder and drill holes, to mention just a few jobs.

The tool is available in a kit form that includes all accessories, such as high-speed steel cutters, emery and silicon grinding wheels and points, wire brushes, felt and rubber polishing points, sanding discs, mandrels, collet wrenches and many more, all of which will be shown and talked about later on in this section.

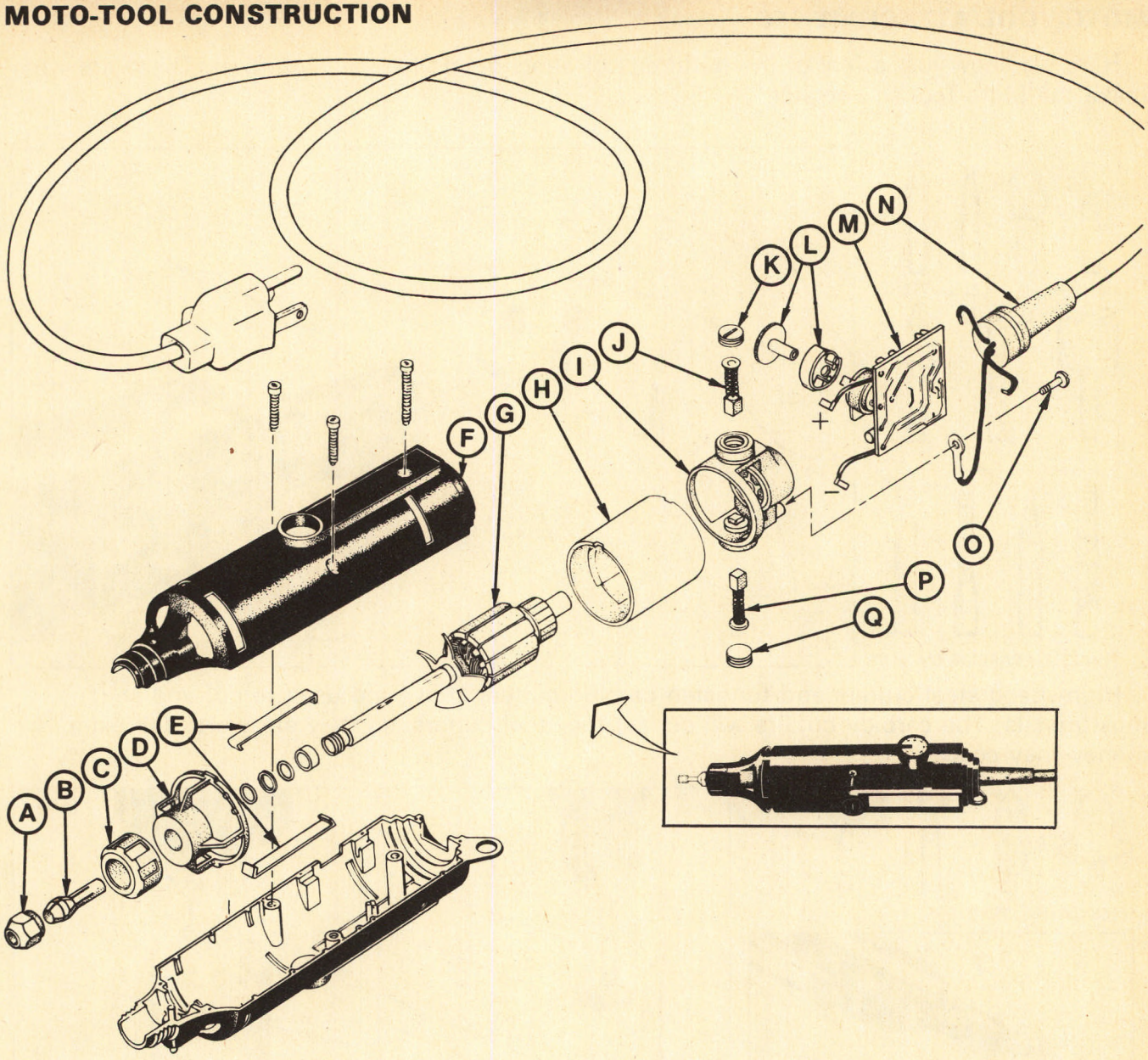
This little tool will turn up to 30,000 rpm (revolutions per minute) and weighs approximately 11 ounces. Most popular hand grinders will stall out under a torque load at approximately 2½ inch-ounces, but the Moto-Tool is so well constructed that it requires approximately 16 inch-ounces to create a stall.

Naturally, this tool is not meant to replace the heavy-duty bench grinder, but it will do all precision chores. Also, you can take the Moto-Tool to your work, wherever you're working. This tool is also great for sharpening small hand tools such as the small chisel and screwdriver and for polishing those hard-to-reach areas on engine parts that it would be impossible to get to with a non-powered hand tool.

Another excellent feature of the Moto-Tool is adjustable power speeds. The selector knob (B) allows you to select seven speed ranges (up to 30,000 rpm), which gives the Moto-Tool great flexibility for any job.



MOTO-TOOL CONSTRUCTION



As you can see, the solid-state Moto-Tool is an extremely well-constructed little hand grinder. Its outside case (F) is made of shockproof nylon, and it runs on a permanent magnetic motor with oil-impregnated (saturated) bronze bearings or ball bearings at 30,000 rpm.

The parts of the Moto-Tool are:

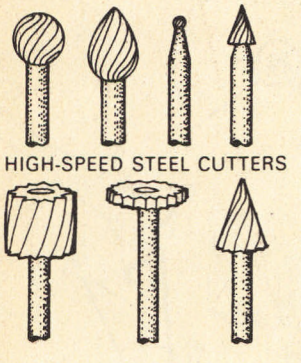
- Chuck cap (A)
- Collet (B), with sizes from 1/32-inch up to 1/8-inch
- Housing cap screw (C)
- Front bearing bracket (D)
- Bearing bracket clips (E)
- Nylon housings (F)
- Armature (G)
- Field with magnets (H)
- Brush caps (K, Q)
- Brushes and shunts (J, P)
- Rear bearing bracket (I)
- Ground screw (O)
- Solid-state module (M)
- Adjustable knob and skirt assembly (L)
- Electrical cord (N)

The guarantee on the Moto-Tool is about the best on the power tool market today (which proves the manufacturer knows he has a darn good product). One promise that few other guarantees make is to return your repaired or replaced Moto-Tool within 72 hours after they receive it. How's that for speed?

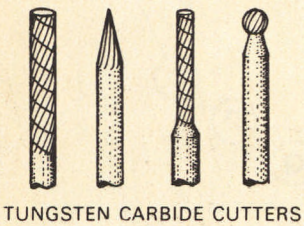
MOTO-TOOLS

MOTO-TOOL ATTACHMENTS

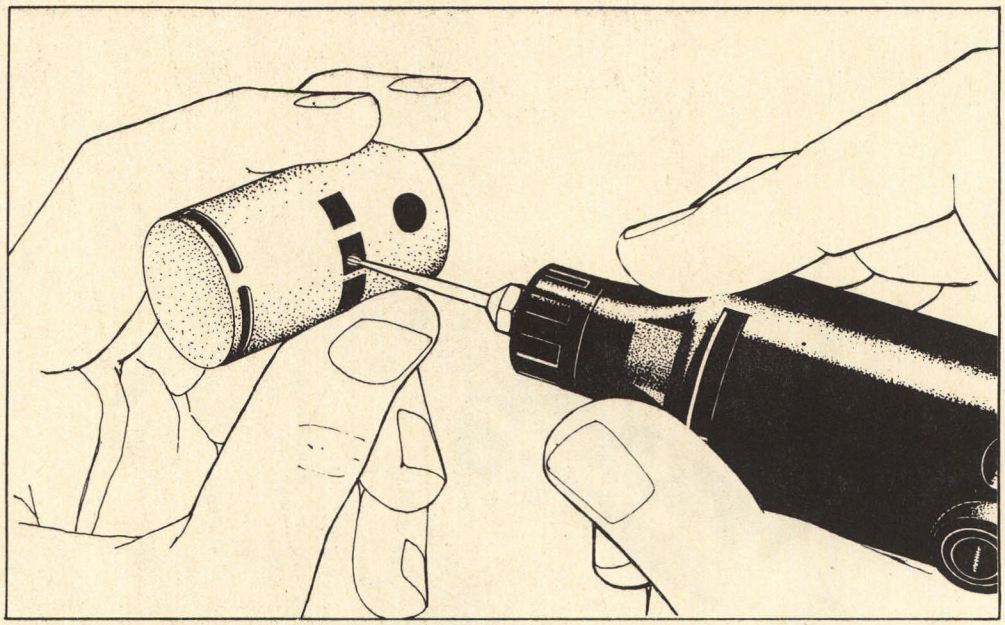
Here we show just a few of the hundreds of attachments for the Moto-Tool. These are what make the Moto-Tool so versatile.



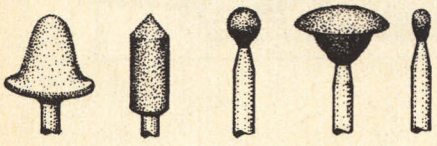
HIGH-SPEED STEEL CUTTERS



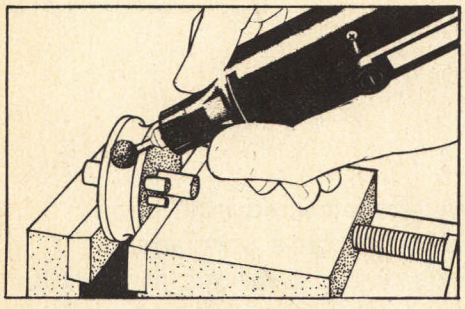
TUNGSTEN CARBIDE CUTTERS

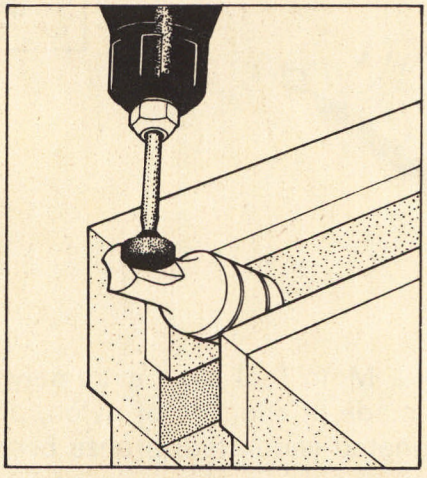


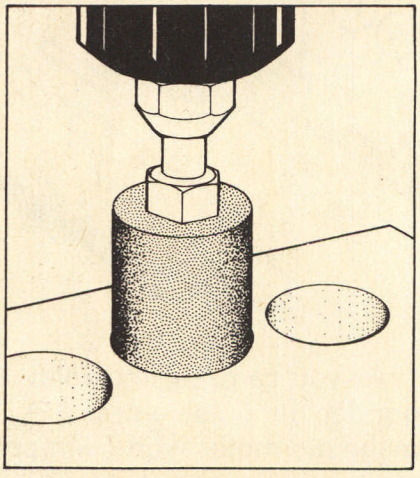
High-speed steel cutters and tungsten carbide cutters above are used to cut and shape most metals. The carbide cutters will outlast the steel cutters, so they are worth the extra money they cost.



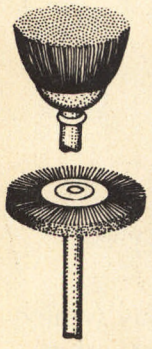
EMERY WHEEL POINTS



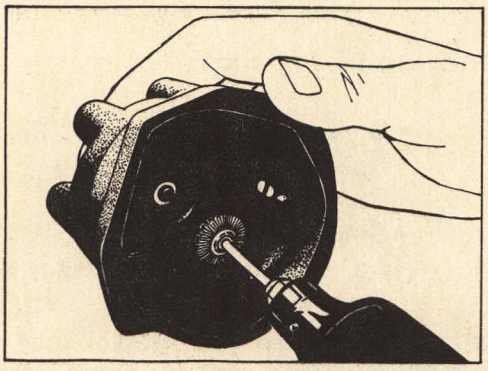


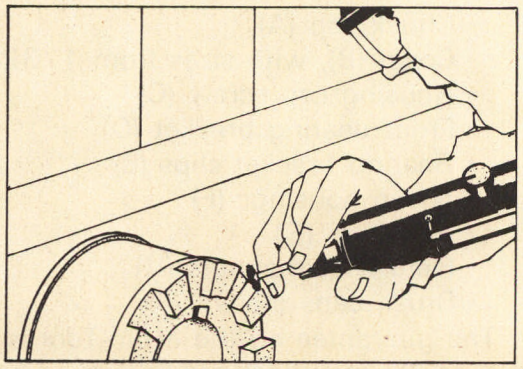


Emery wheel points above are made of quality abrasives and used to polish, bore and sharpen.

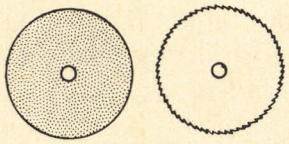


BRUSHES

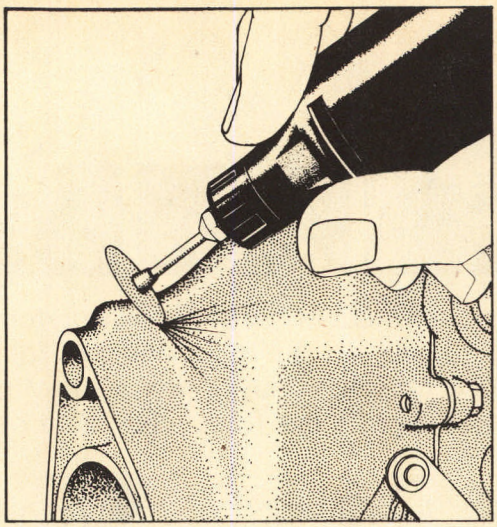


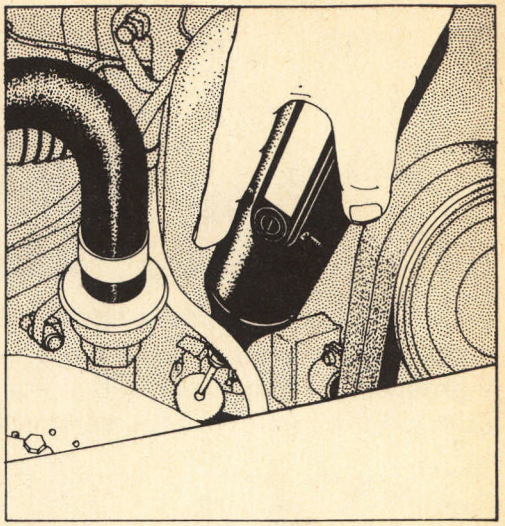


Wire brushes remove rust and polish metal surfaces. They are also available in a bristle brush for lighter polishing and cleaning.

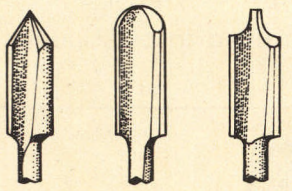


CUTTING WHEELS

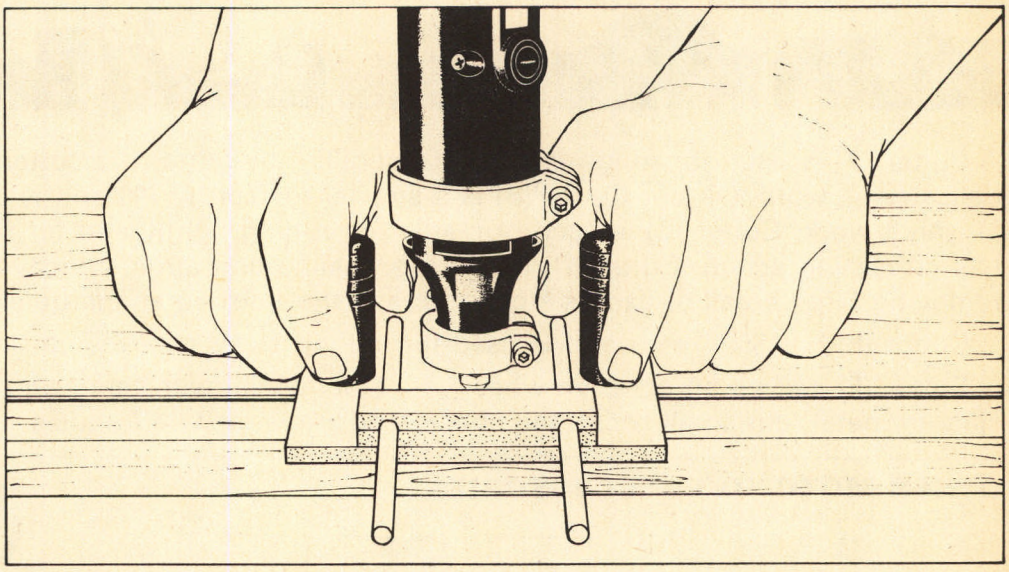




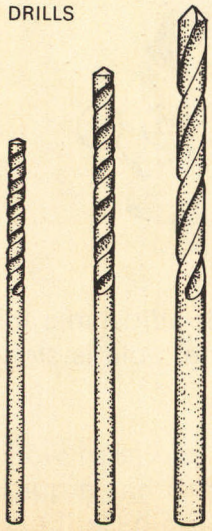
Cutting wheels: One is an emery wheel and the other has saw teeth for cutting tubing or frozen hose clamps.



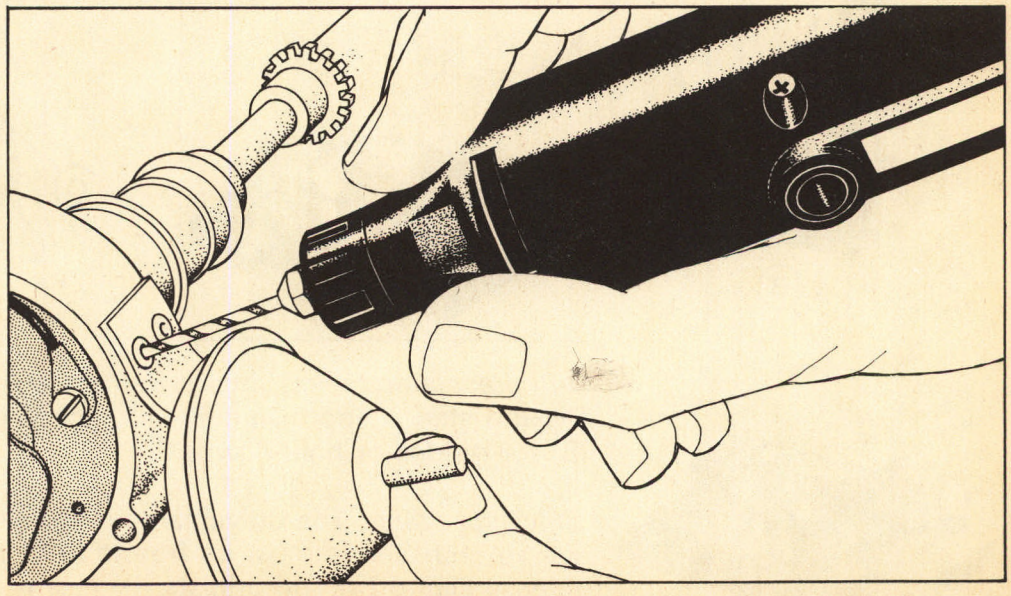
HIGH-SPEED STEEL ROUTERS



High-speed steel routers above are used for routing holes in metal or other material to a larger size.

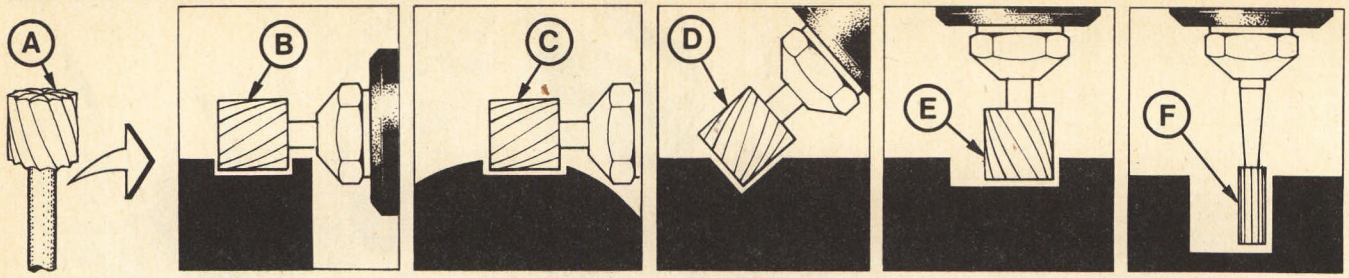


DRILLS

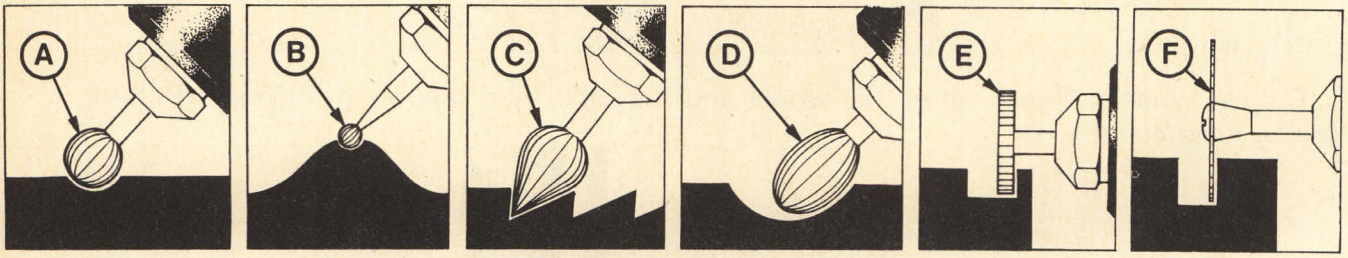


Drills are for drilling those small, hard-to-reach areas on an engine.

TYPES OF SURFACE CUTS



Cutter (A) is the most popular and useful cutter made. It will perform about 80% of all types of cutting. It will cut flat areas (B), flatten the top surface of rounded areas (C), will cut V-grooves (D) and carve odd-shaped sections to a flat bottom using the end of the cutter (E). Cutter (F) is just a smaller version of (A) and is used for finer, more detailed work.

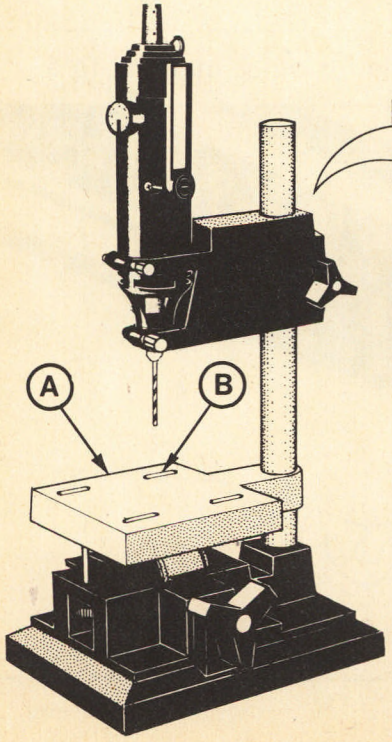


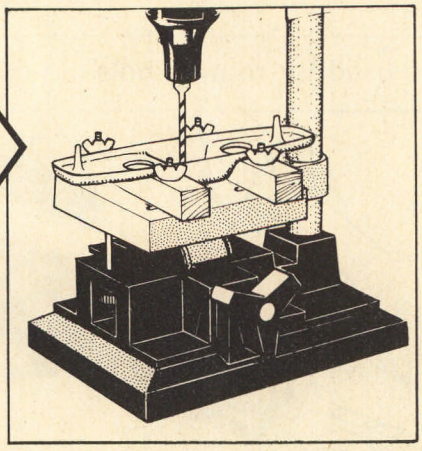
Cutter (A) is used for rough carving. Generally, the larger the cutter, the less detailed and delicate the work will be. Cutter (B) is a smaller version of (A) and is used for delicate finishing work. Cutter (C) is used primarily for cutting lightly and for finishing. The point itself has no cutting action. Cutter (D) is used for fast-cutting large, concave shapes and for removing large areas of excess stock to reach the finished shape quickly.

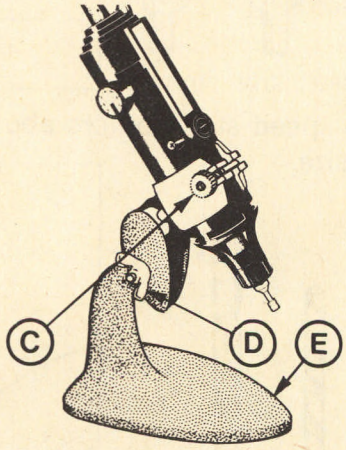
Cutter (E) has saw teeth and is used for cutting slots, grooves and angles in material.

Cutter (F) can be an abrasive wheel or a steel wheel with teeth and is used to cut deeper slots in metal, cut small rods, thin sheets and wires or wire bundles.

OTHER MOTO-TOOL ACCESSORIES

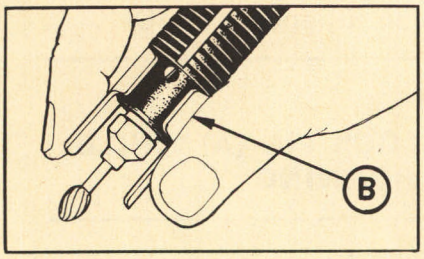






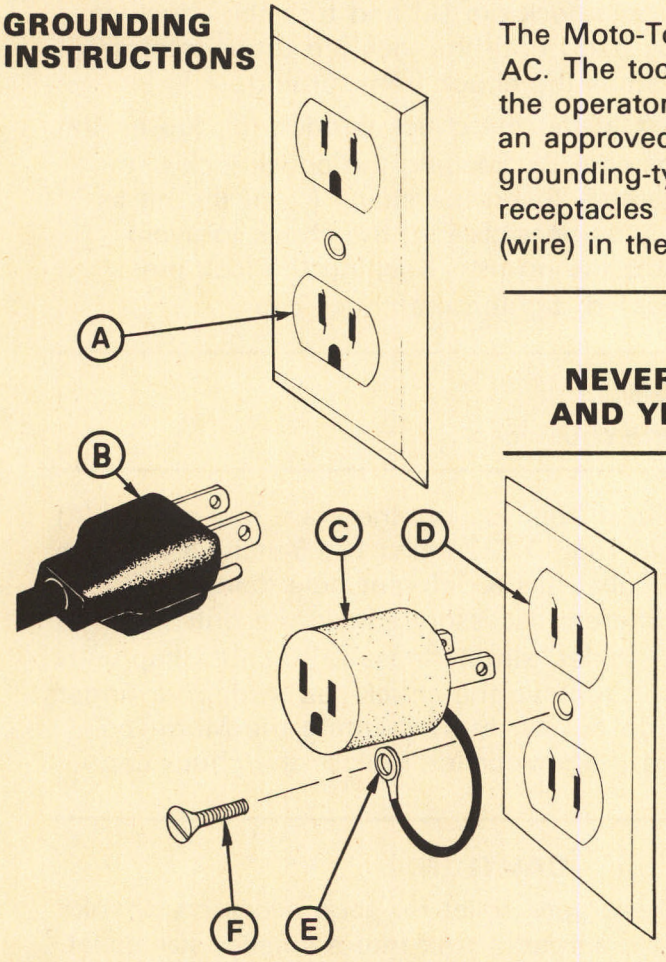
Drill press stand: This little jewel has a 4×4-inch adjustable table (A) and stands approximately 12 inches high. The table is slotted (B) for guides or hold-downs.

Universal stand: The universal stand is great for precision work, where both hands must be free to hold the part. It has a quick-release clamp (C) and adjusts (D) to any angle. The base (E) is extra heavy to prevent accidental tipping.



Moto-Tool flexible shaft: This flexible shaft (A) attaches to the Moto-Tool and is used like a pencil. Its flexibility allows you to cut or polish areas that are hard to reach or would not allow the normal Moto-Tool to enter. It's also used for high-precision work and comes with an adapter (B) for safer, more secure holding power.

GROUNDING INSTRUCTIONS

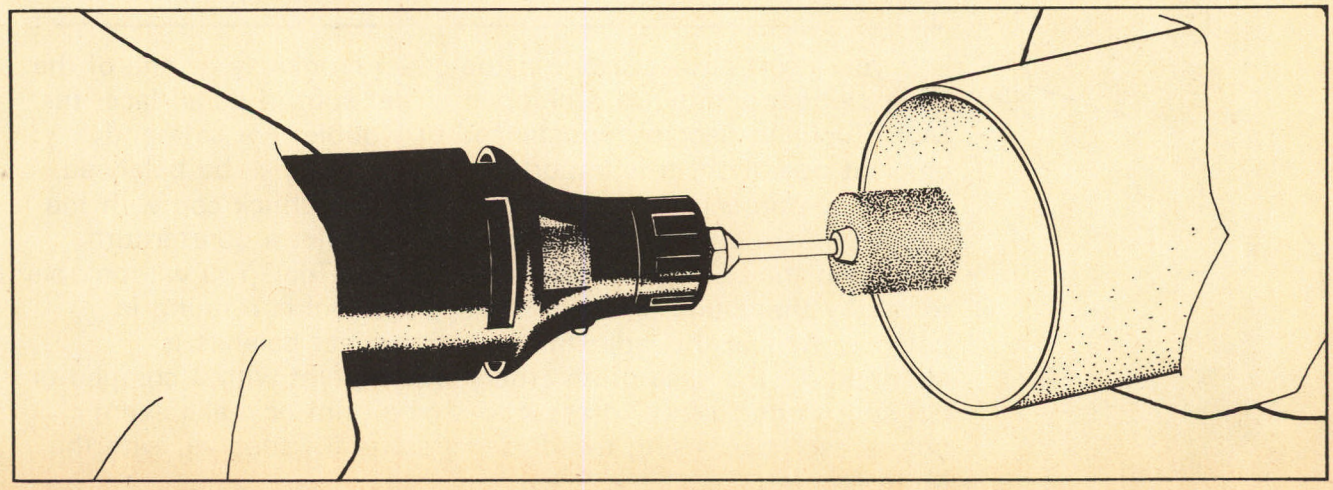


The Moto-Tool is designed to operate on 115V, 60-cycle AC. The tool should be grounded while in use to protect the operator from electrical shock. The tool is equipped with an approved three-conductor cord (wire) and three-pronged grounding-type plug (B) to fit the proper grounding-type receptacles (A). The green (or green and yellow) conductor (wire) in the cord is the grounding wire.

WARNING

NEVER CONNECT THE GREEN (OR GREEN AND YELLOW) WIRE TO A LIVE TERMINAL.

An adapter (C) is available for connecting plugs (B) to two-pronged receptacles (D). The green (or green and yellow) grounding wire (E) extending from the adapter must be connected to a permanent ground, such as a properly grounded outlet box. Wire (E) is usually attached to the center screw (F) that holds the electrical box cover on. This is usually a good ground. Use only three-wire extension cords which have three-pronged, grounding-type plugs and three-pole receptacles which accept the tool's plug. Replace or repair damaged or worn cords immediately.



HOW TO OPERATE THE MOTO-TOOL

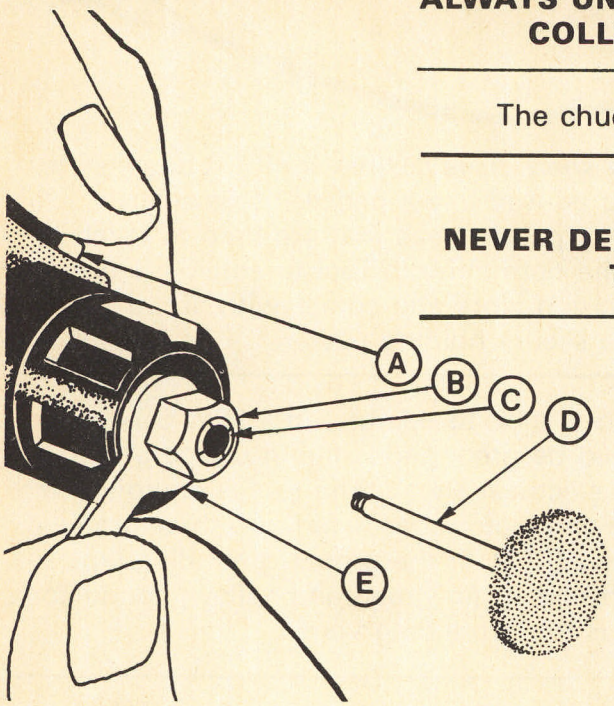
WARNING

ALWAYS UNPLUG THE MOTO-TOOL WHEN CHANGING COLLETS OR INSERTING ATTACHMENTS.

The chuck consists of a chuck cap (B) and collet (C).

WARNING

NEVER DEPRESS THE CHUCK LOCK PIN (A) WHILE THE MOTO-TOOL IS RUNNING.

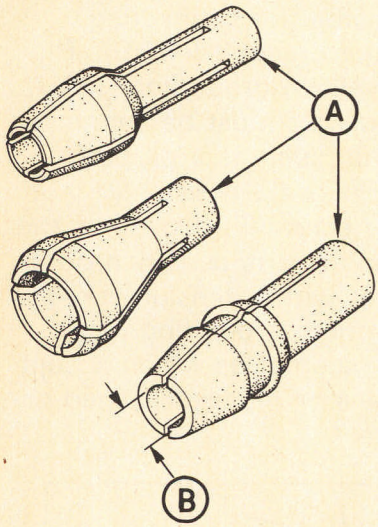


To change or inset bits (attachments), press the chuck lock pin (A) and turn the chuck cap (B) by hand until the lock pin drops into place and stops the chuck from turning.

Next, using the chuck wrench (E), loosen the chuck cap (B), keeping the chuck lock pin depressed. Insert the shank (D) of the bit as deeply as possible into the chuck to avoid wobble during use. Keeping the lock pin depressed, tighten the chuck cap.

CAUTION

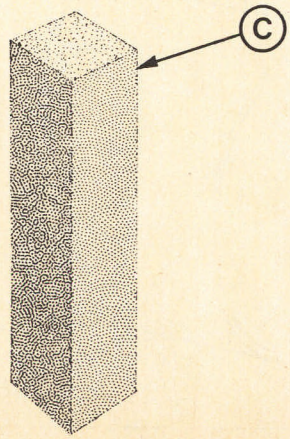
Do not overtighten the chuck cap.



As we stated earlier in this section, there are four collets (A) available for the Moto-Tool: 1/32-inch, 1/16-inch, 3/32-inch and 1/8-inch. Each collet has a different hole diameter (B) in order to accept different accessory shank and drill sizes. To insert a different size collet, simply loosen the chuck cap with the chuck wrench and remove the chuck cap with your fingers. The collet should drop out easily by pointing the Moto-Tool down. After inserting the new collet, replace the chuck cap.

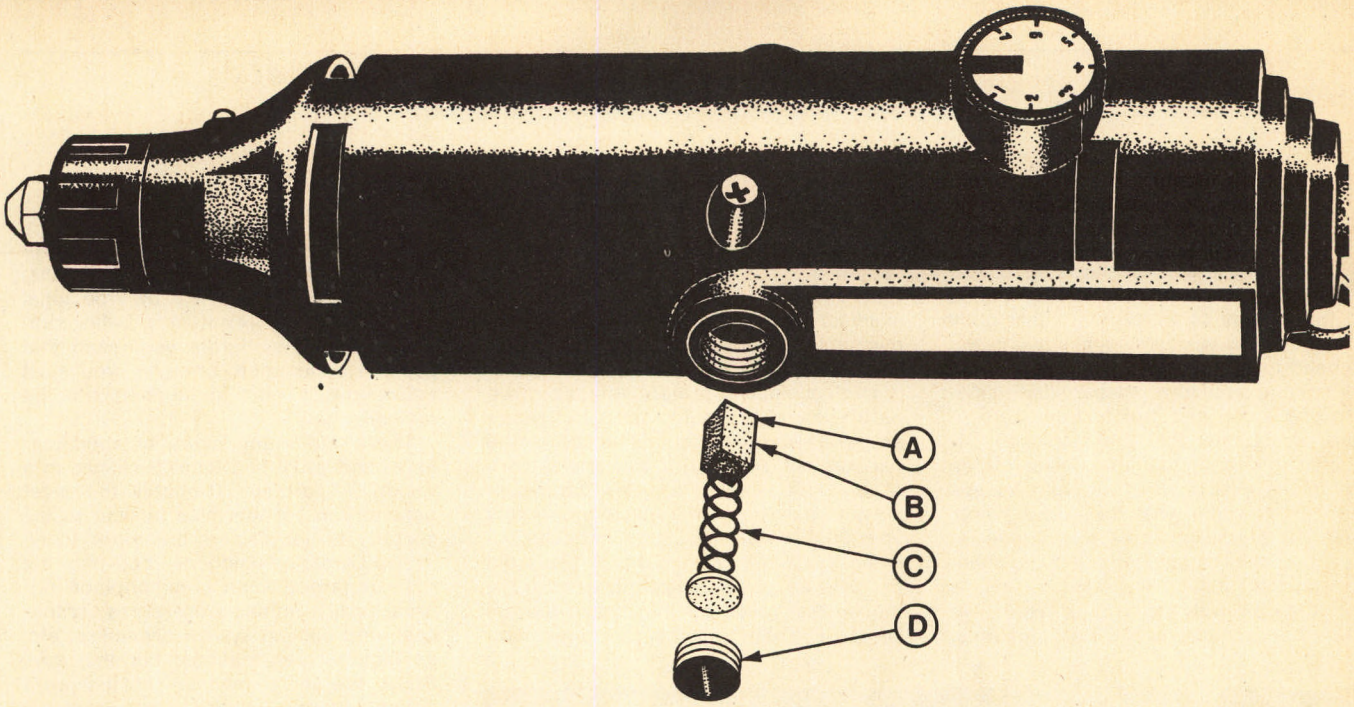
CAUTION

Be sure to select the proper collet for each accessory shank. Never force a larger diameter shank into a smaller size collet.



If you insert an accessory in the collet crookedly or one of the emery wheel points has a chipped or flat spot in its surface, the Moto-Tool can become unbalanced or wobble. For safe and efficient operation, it is important that accessories be balanced. To balance an accessory, slightly loosen the chuck cap with the chuck wrench and give the accessory or collet a quarter-turn. Retighten the chuck cap and run the Moto-Tool. You will be able to tell by the sound and feel if the Moto-Tool is running in balance. Repeat this adjustment until perfect balance is obtained. In the case of an emery wheel point with a chipped or flat spot in its surface, dress it to shape (trim or make even) before each use, using the dressing stone (C) supplied with the Moto-Tool kit.

CARE OF THE MOTO-TOOL

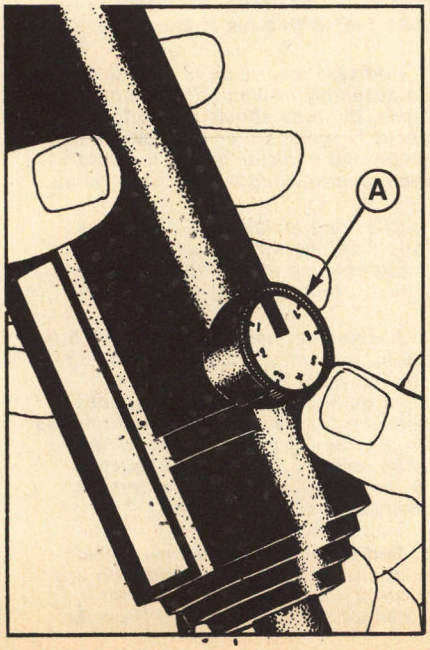


CAUTION

Be sure to unplug the Moto-Tool before changing the motor brushes.

The brushes (B) should be checked for wear every 20 hours of operation. The brushes are located under the two screw caps (D) near the middle of the Moto-Tool. When the brushes have worn down to approximately 1/16-inch from the springs (C), they should be replaced.

After checking brushes and finding them still good, be sure you reinstall them into the same brush holder from which they were removed. When installing new brushes, be sure the curved brush ends (A) are installed so that they follow the curvature of the commutator of the motor inside the unit.



Different materials, such as plastics and metals, require different speeds to get through them conveniently. The Moto-Tool has this handy feature, allowing you to go from very slow speeds (range 1 and 2) to very fast speeds (range 6 and 7) via a speed selector dial (A).

The slow speed ranges should be used for delicate work as on plastics or when polishing with a wire or bristle brush. The highest speeds are used for shaping edges, cutting metal or drilling. Always select the right speed for each job. The degree of success you achieve with the Moto-Tool depends upon the skill you develop in operating it. Knowing your cutting speeds in relation to the material being cut, knowing your safety rules of operation and using the tool often in varied ways will make the Moto-Tool an invaluable mechanical companion. You should practice on scrap material until you have mastered the Moto-Tool's many uses. Remember, the tool will do a lot of work, but don't force it to perform beyond its capacity.

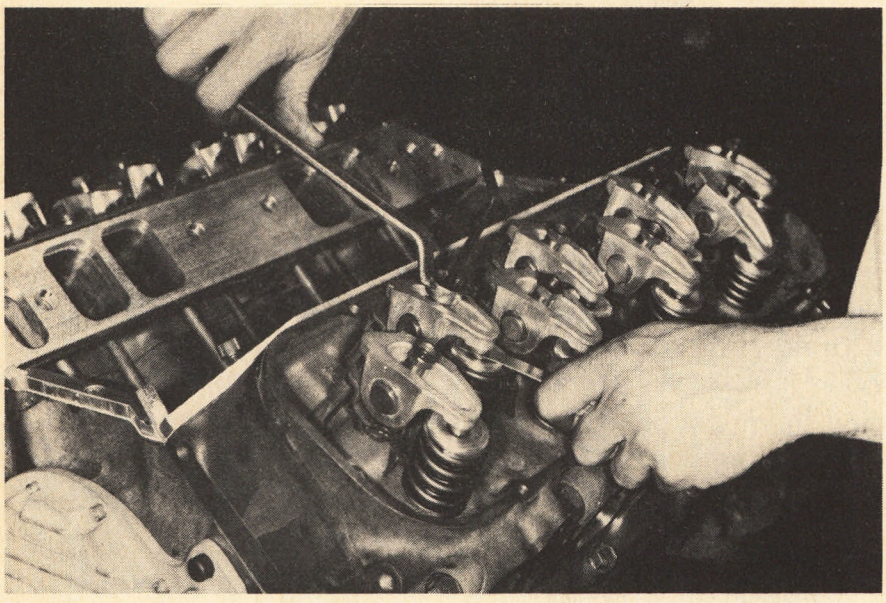
Specifications--What They Mean

A specification can be anything from a description of the type of material used in upholstering fabrics to the amount of air pressure that goes in a tire. How you use specifications will depend to a great extent on the amount of training you have had in doing mechanical work, and also on your personality. If you feel that the men who designed and built the automobile in the first place were a bunch of stumblebums who didn't know what they were doing, then you probably will have very little respect for their specifications. A mechanic with that attitude is bound to have a lot of trouble with the cars he repairs. At the other extreme is the car repairman who feels that the Detroit engineers have set up the specifications as strict laws that cannot be violated in even the slightest degree. Strangely enough, the mechanic who has that attitude will also find repairing cars to be rather difficult.

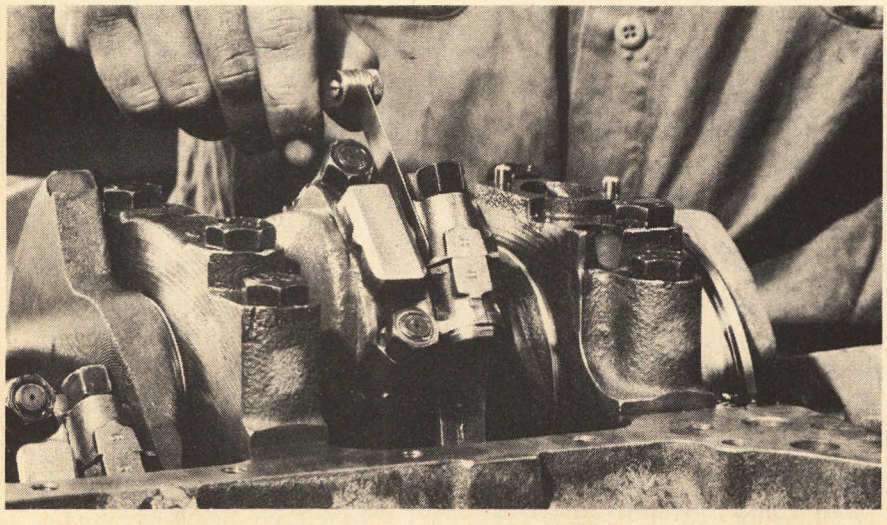
The specifications were not laid down as the law of the automobile, but rather as guides to show the mechanic how the car was set up when it was brand new. A mechanic working in a new car dealer service department will follow the factory specifications as closely as possible, but when a car is 2 years old or 5 years old or 10 years old, it is not the same automobile that rolled off the end of the assembly line. The result is that a mechanic has to realize that a slight departure from the original factory specifications, based on the mechanic's own personal experience, may result in a better running automobile. Before you reach that point in experience, however, you must know how to read and understand the factory specs.

There are many types of specifications, and you'll find them published in a variety of formats. Probably the most general and yet the most familiar to the majority of car owners are those found in the Owner's Handbook. You may not have regarded such commonplace figures as tire inflation pressures, crankcase and cooling system capacities, etc. as factory specifications, but they are. So if the mere mention of the word "specifications" conjures up visions of incomprehensible data, set your mind at ease and follow along as we explore the world of specifications—where to find them and what to do once you've got them.

If you've done any work at all under the hood and your car is a recent model, you've probably noticed a label, sticker, or decal marked Vehicle Emission Control Information. While you might not have thought of it as such, this is really a basic spec chart complete with instructions on how to interpret and apply the information it contains. With nothing more than this chart and a few simple tools, you can keep your engine tuned to



1. Checking Valve Lash



2. Rod Side Clearance

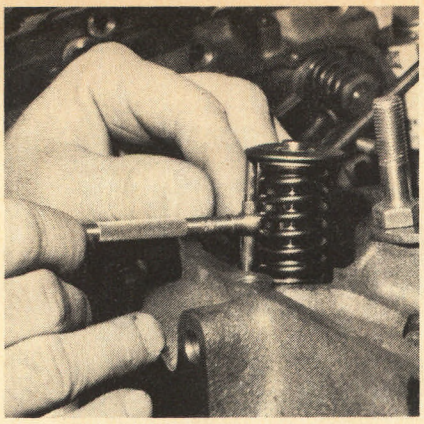
1. Clearances can be quite important on stock engine setups; on high-perf machinery they're critical. Here the rocker arm adjustment is checked for valve lash with a feeler gauge.

2. Rod side clearance is checked on assembly in block. If it's too close, the rods should be switched about or replaced, or the sides must be ground sufficiently to fall within the recommended factory spec range.

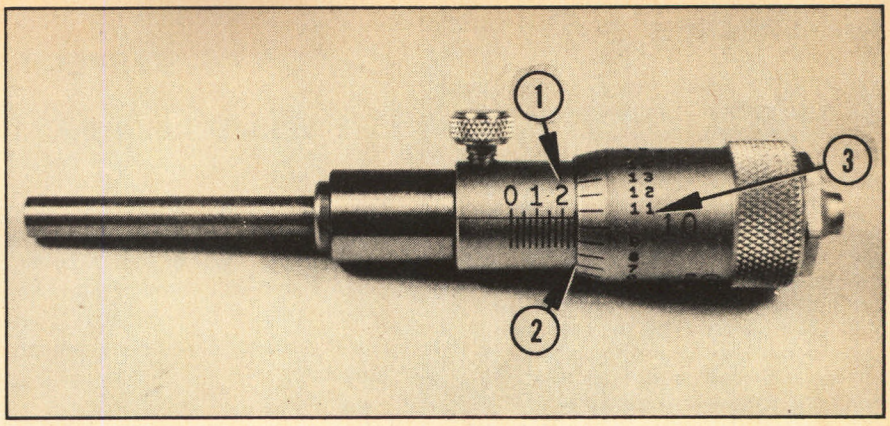
3. Checking installed valve springs for equal height and pressure is an important step in setting up valve action for high-rpm operation.

4. Assembled inside mike has a 2.5 to 3.5-in. rod and .5-in. sleeve, making starting point 3.0 ins. Numbered lines on hub (1) are tenths; spaces between (2) are each .025-in. Numbers on thimble (3) are in thousandths of an inch (reading shows between .010-.011.). The total measurement indicated here is 3.260 ins.

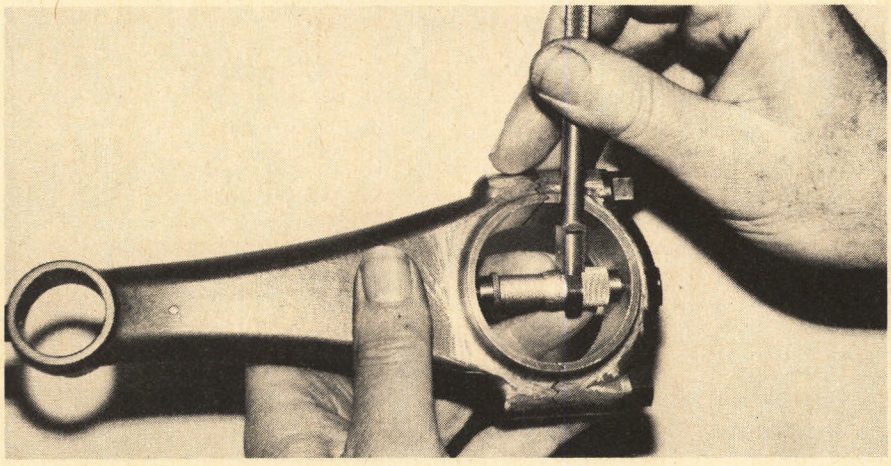
5. Rod bore is measured with inside micrometer. Extension handle on this mike is just an easy way to hold it; it cannot be used to adjust the mike.



3. Checking Valve Spring Height



4. "Inside" Micrometer



5. Measuring Rod Big End Bore

factory settings. But many specs are a good deal more exotic; they require that you have a knowledge of exactly where they can be located, as well as a deeper understanding of what makes your car tick.

SOURCES FOR SPECS

There are many sources for factory specifications. Independent companies produce repair manuals that have specs, and many parts companies give out booklets of specifications so that their parts will be installed correctly. The original specifications for all cars are printed by the car maker in what is called the "Shop Manual." Every year about the time that the new cars come out, a new "shop manual" is issued to be used any time that year's car is worked on.

The unfortunate thing about shop manuals is that, in most cases, they are printed before any of the new cars actually hit the street. The result is that there are many changes in specifications and repair procedures during the model year that do not appear in the shop manual. The manufacturer takes care of this—as far his own dealers and repair facilities are concerned—by issuing service bulletins on a regular basis.

Some of the manufacturers do not care who does the repairs on their cars, just so they are done correctly. They will send their service bulletins to any legitimate repair facility. Other manufacturers consider their service bulletins in the same light as top secret war communiques, and will not allow anyone outside of their own organizations to see them. This attitude works a definite hardship on the independent garage or service station who has new car customers. If the service bulletins were distributed to all repair outlets, it would be great for the trade, but what good would it do you as an individual car owner who wants to fix his car on a Saturday afternoon? Unfortunately there is no way at present for a car owner to obtain service bulletins, either for pay or for free. But you can buy all the service manuals that you want, even going back as far as 15 years.

If you are interested in factory service manuals, the address to write for them is usually in the back of the owner's manual that comes in the glove compartment of your car; or you can get the address from any dealer who sells the make of car you are interested in. Now let's take a look at what some of the specifications mean.

Dimensions are directly related to performance because of a compromise necessary in mass production known as tolerances. If every moving part had to perfectly fit its mating surface, the car makers wouldn't be able to produce 9 million cars a year. Therefore, tolerances are allowed which compensate for the imperfections inherent in both man and machine without seriously affecting the proper function of the car. For example, in a popular current V-8 engine, the maker specifies a tolerable variance of from .0007 to .0027-in. in the clearance between the connecting rod bearings and the crankshaft. In the course of a day's production which is in the thousands of units, and with hundreds of parts involved in each unit, the law of averages sees to it that there will be "tight" fits, "loose" fits and very occasionally, an "ideal" fit. This is the reason why one man's car will go a few miles faster and get a few more miles per gallon than the identical car belonging to his neighbor. It is also the reason why skilled racing mechanics can extract upwards of 600 hp from a "stock" engine that is rated at maybe 400 hp by the factory. They painstakingly "blueprint" every part, honing it to its precisely ideal tolerance—and the resulting collection of parts sings like no engine ever to leave the factories in Detroit.

SAMPLE ENGINE DATA

To give you an idea how to interpret specs, we have reprinted the accompanying chart verbatim from the 1973 Chevrolet factory shop manual. It shows engine data for a group of engines used in Chevrolet cars and trucks. Where an explanation seems necessary, the numbers alongside each item are keyed to the following text.

1) Horsepower and torque are measured by the factory under standardized conditions, and the figures "claimed" are those for the most favorable engine speed. A higher engine speed won't necessarily result in a higher horsepower or torque unless cam configuration and other components are altered. We say "claimed" because auto makers have in the past made free use of an "educated pencil" in assigning horsepower figures to their engines. In 1972, this situation was reversed, with the manufacturers using "net" figures that are decidedly on the pessimistic side to please the government safety bureaucrats and insurance companies.

2) Bore and stroke dimensions govern engine displacement. Usually you can overbore up to .030-in. without weakening the block structure, and it is common hot rod practice to "stroke" the engine by welding and regrinding the crankshaft connecting rod journals, and thus increase the distance traveled by the piston. Either or both of these procedures will increase the displacement and, thus, the power output.

3) The higher the compression ratio, the greater the pressure in the combustion chamber, and the greater the horse-

power output. Ratios over 8.5:1 usually require premium high-octane gasoline.

4) Firing order alone is not enough to enable you to run the wires from the distributor cap to the spark plugs correctly. You must also have the cylinder numbering, which is not given here. Sixes are numbered front to rear, consecutively. General Motors V-8's have the evens on the right and the odds on the left. Ford products have 1 to 4 on the right, and 5 to 8 on the left. Cylinder numbering is sometimes embossed on the intake manifold right above each cylinder.

5) Bore diameter on these engines varies about .003-in., but piston clearance in the bore is in most cases considerably less than that. (Pistons come in different sizes and are select-fitted to each bore.) Small shops do not have the luxury of an unlimited supply of different size pistons, so when they rebuild an engine they simply buy one set of pistons and bore each cylinder to fit a particular piston.

6) Throughout the chart, specs are listed as either "production" or "service." The "service" dimension is a wear limit. If it is exceeded, the part must be reconditioned or replaced.

7) Taper in the cylinder bore is extremely hard on the rings; it causes them to flex and wear out as the piston strokes up and down. Measuring taper on the thrust and relief sides of the bore is like splitting hairs. The relief sides of the bore are the front and rear, 90° from the thrust sides where the piston skirt slides. Excessive taper requires a cylinder rebore.

8) If piston clearance exceeds the service wear limit, the engine will have to be overhauled or rebuilt. There are several ways to get the piston clearance within limits. The old pistons can be knurled; new pistons can be fitted; or the cylinders can be bored to fit some new pistons.

9) Piston ring groove clearance is the difference between the vertical thickness of the ring and the vertical measurement of the groove. If the rings are too tight in the groove they will not be free to put pressure on the cylinder wall. If they're too loose, combustion pressure or oil will find its way around the back side of the ring, and the result will be lower performance. Ring gap is not critical, as shown by the great tolerance, but gaps too close may allow ring ends to butt, which can ruin the rings. Service wear limit is found by adding the figure shown to the production high limit, which in the case of groove clearance on the 307 2nd ring would be .0032 plus .001, for a total of .0042-in.

10) Clearance refers to clearance between the piston pin and the pin bosses. The interference fit specified in the rod means that the pin is larger than the hole in the rod by the dimension shown, which results in a press fit.

11) Main bearing journals are numbered from front to back. Note that there is about .001-in. tolerance on the journal size. A crank ground to the low end of the specs would have more clearance in the bearings, and would be a freer turning crank. Worn cranks are customarily reground .010, .020, or .030-in. undersize, and used with thicker bearings.

12) Main bearing (and rod bearing) clearance is usually controlled by the diameter of the crank journals, because bearings usually come in one standard size. However, some manufacturers make bearings that vary by tenths of thousandths, allowing clearance to be controlled by select-fitting. Note the reduced clearance on the front main, and increased clearance on the rear. The front main has to be tighter or it may knock before oil pressure rises when the engine is started up, due to load of belt-driven accessories on the front pulley. Rear main has increased clearance for more oil flow, because it is heavily loaded by the power flow and needs oil.

13) "Crankpin" means the same as "rod journal." The same methods of obtaining clearance apply here as on main bearings.

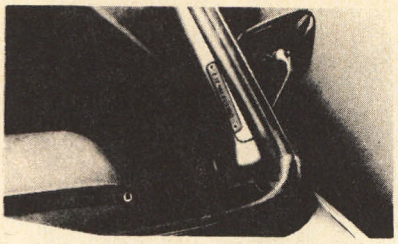
14) Lobe lift is different from valve lift. Lobe lift can be measured on the cam with a micrometer. Valve lift is usually greater than lobe lift, because of rocker arm ratio.

15) Hydraulic lifters have an internal spring that takes up the play in the valve train when the valve is closed. "Zero lash" means that the adjusting screw in

SPECIFICATIONS

VEHICLE IDENTIFICATION NUMBER LOCATION

Your vehicle identification number is stamped on a metal tab located on the driver's side of vehicle on the pillar post, visible through the windshield. This is the official number that is used for car title registration purposes.



VEHICLE SPECIFICATIONS

DIMENSIONS AND WEIGHT

Wheelbase	100.8 inches
Overall length	167.8 inches
Overall width	64.8 inches
Overall height	50.7 inches
Turning circle	34 ft.
Ground clearance	5.0 inches
Curb weight: 2000 CC Std. Transmission	2266 pounds
Auto. Transmission	2299 pounds
2600 CC Std. Transmission	2293 pounds
Auto. Transmission	2326 pounds

ENGINE SPECIFICATIONS

Refer to the "Emission System Warranty and Maintenance Schedules" Booklet for the Engine Specifications.

ENGINE LUBRICATION	2000 CC	2600 CC
Oil Pan Capacity—Without Filter	3.5 US Quarts	4.0 US Quarts
—With Filter	4.0 US Quarts	4.5 US Quarts
Oil Pressure	34 Min. psi @2000 RPM	40 Min. psi @ 2000 RPM
FUEL SYSTEM		
Tank Capacity	12 US Gallons	
Fuel Pump	Mechanical Diaphragm	
CARBURETOR		
Type	Weber— Two Venturi	
COOLING SYSTEM		
Type	Pressure Vented (13 psi)	
Thermostat	Wax Capsular Open at 185–192°F	Wax Capsular Open at 183–190°F
Capacity (with Heater)	6.5 US Quarts	8.2 Quarts (Std.) 8.4 Quarts (H.D.)
CLUTCH		
Type	Single Disc	
Diameter (inches)	8.5	9.5

1. Typical Manual Specs

1. Capri owner's manual contains general specs of concern to all drivers.

VEHICLE SPECIFICATIONS (Cont'd)

MANUAL TRANSMISSION	2000 CC	2600 CC
Type	4 Speeds Forward One Reverse (Fully Synchronized in all Forward Gears).	
Lubricant Capacity	2.8 US Pints	
Lubricant	SAE 80 E.P.	
Ratios (Overall)	First – 3.65 Second – 1.97 Third – 1.37 Fourth – 1.00 Reverse – 3.66	
AUTOMATIC TRANSMISSION		
Type	C-4	
Lubricant Capacity	14.80 US Pints	
Lubricant	12.50 US Pints	
REAR AXLE		
Type	Rigid Axle with Radius Arms	
Ratios	3.44	3.22
Lubricant Capacity	2.32 US Pints	
Lubricant	ESW-M2C105-B	
STEERING GEAR		
Type	Rack and Pinion	
Lubricant Capacity	0.25 US Pints	
Lubricant	M2C-28B SAE 90	
FRONT SUSPENSION		
Type	McPherson Strut	
Toe-in	o to 1/4"	
Track (inches) – Front – Rear	53.0 52.0	
REAR SUSPENSION		
Type	Semi Elliptic Leaf Springs with Radius Arms	
BRAKES		
Dual Line System	Power Assisted	
Front	Disc	
Rear	Drum	
Parking Brake	Mechanical (only rear)	
Disc Diameter (inches)	9.62	
Fluid	ESA–M6C 25–A	
Rear Drum Diameter (inches)	9.00	
WHEELS		
Type	5J x 13	
TIRES		
Standard	165–SR x 13 Radial Ply	185–70 HRX x 13 Radial Ply
Optional	185–70 SR x 13 Radial Ply	– – – –

the rocker arm is turned down until the pushrod is just starting to compress the lifter spring. One turn additional puts the valve train within the lifter's operating range. If the rocker arm does not have an adjusting screw, this job must be done by changing to different length pushrods.

16) Face and seat angles are always measured from the horizontal. The increased angle on the seat insures that the upper edge of the seat will meet the valve with line contact, which has less tendency to leak than a seat that meets the valve squarely over its whole face. After a few miles, the valves pound in and seat over the whole face.

17) Wide valve seats cool the valve better, but have more tendency to leak. Narrow seats seal better, but they pound out easily. Seats are probably going to get wider in years to come, so they will live longer with unleaded gasoline.

18) Stem clearance is not critical, except that excessive clearance can allow too much oil to be sucked down the guides into the combustion chamber. Worn guides can be renewed several ways: They can be reamed out, which requires the use of valves with oversize stems; they can have bronze inserts installed and used with standard size valves; or, in some cases, the guides can be replaced.

19) Valve spring pressure is checked on a test fixture at the indicated length in inches. A bathroom scale and a drill press work fine, too. Weak springs must be discarded. Note that the installed height is equal to the "spring closed" checking dimension. If installed height is too much, spring pressure will be low, and valves may leak and burn. Too little height increases spring pressure, and can result in a worn out cam lobe or a bent pushrod from coil bind. When seats and valves are ground, installed height increases, and must be brought back to specs with special washers installed between the spring and the head.

Next to a good engine tune-up, most cars on the road today could use a front-wheel alignment check. And you'd probably find about 50% of all those over one year old sadly lacking when compared to factory specifications. Front-wheel alignment is really a very simple matter, but the specialized equipment necessary to do the job properly is seldom found outside a repair shop. Yet a knowledge of what's involved can be of help to anyone who takes the time to work on his own car.

The three adjustments involved in wheel alignment are caster, camber, and toe. Caster is the tilt (front or back) of the top of the wheel spindle; positive caster is tilt to the rear, negative caster is tilt to the front. Camber is the amount of tilt at the top of the wheel; outward tilt is positive camber, inward tilt is negative camber. Toe is the difference between the measurement at the extreme front and extreme rear of the front wheels. If the front measurement exceeds that of the rear, it's called toe-out; when the rear exceeds the front, it's known as toe-in. The accompanying specifications provided the minimum and maximum allowable distances for 1972 Fords when checked under curb load conditions.

GEAR AND AXLE RATIOS

Normally, a customer has no choice in the gear ratios of an automatic transmission unless he has the unit rebuilt and "blueprinted" to his preferred specs by an independent specialist. A choice is sometimes offered in the lower gear ratios of 3- and 4-speed manual transmissions that can alter acceleration potential. If there is a pronounced spread between the lower ratios of a transmission, the unit is known as a "wide ratio," and is probably more suitable for normal driving. Conversely, a lesser spread is known as a "close ratio," and is the one to be preferred for road racing or performance cars. In any case, the final or "high" gear is always a 1:1 ratio except, of course, in the case of an overdrive-equipped transmission.

Practically all auto makers, on the other hand, offer a fairly wide choice of rear-end gears. These can range from as "high" as 2.5:1 to as "low" as 4.5:1 on modern cars. The terminology is admittedly confusing, but the word "high" as used here means a high car speed in relation to engine rpm, a combination that will give greater economy and possibly speed (depending upon engine size) but less acceleration potential. "Low" is the opposite condition. A practical gear for street use with a medium-sized V-8 engine is around 3.5:1, or for fast accel-

Specifications

eration 4.11:1. As the engine increases in displacement and, thus, torque output, gearing can drop to 2.5 or so and still produce equivalent acceleration. Also, other factors that must be considered in the choice of rear-end gears are the weight of the car and whether or not you plan to tow trailers. In general, the more load, the "lower" the gear required.

Another way to describe gearing is to use the word ratio. A "high" gear such as the 2.5 described above, would be called a "low-ratio" gear. If you had a set of 4.11's in the rear end, they could be called "high-ratio" gears or, if you like the other terminology, "low gears." Admittedly, it can be confusing, but in one case we are about the numerical value of the ratio, so the bigger the number, the higher the ratio, as with the 4.11's.

But in the other case we are describing the performance of the gears, which have lots of power at low speeds because they let the car get moving easier. So we call the set of 4.11 gears a low gear, and a 2.5 gear-set would be a high gear.

Every so often someone comes out with a new specification, or at least one that you never heard of before. A knowledge of basic specs will help, because the new dimension or tolerance can not really be much different from the basic specs you know so well, if you really know them.

SPECIFICATIONS—1971 CHEVROLET ENGINES

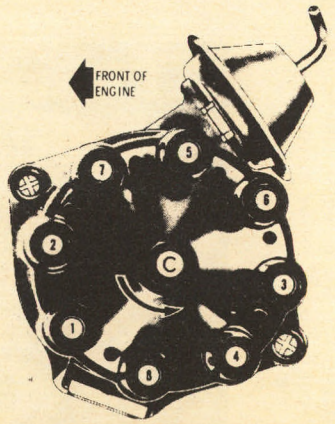
	GENERAL DATA:							
	Type		In Line		V8			
	Displacement (cu. in.)		250	292	307		350	402
1	Horsepower @ rpm		145 @ 4200	165 @4000	200 @ 4600	215 @ 4800	250 @ 4600	300 @ 4800
2	Torque @ rpm		230 @ 1600	270 @ 1600	300 @ 2400	305 @ 2800	350 @ 3000	400 @ 3200
3	Bore		3-7/8		3-7/8		4	4-1/8
4	Stroke		3.53	4.12	3.25		3.48	3.76
	Compression Ratio		8.5:1	8.0:1	8.5:1		8.5:1	8.5:1
	Firing Order		1 - 5 - 3 - 6 - 2 - 4		1 - 8 - 4 - 3 - 6 - 5 - 7 - 2			
	CYLINDER BORE:							
5	Diameter		3.8745 - 3.8775		3.8745 - 3.8775		3.9995 - 4.0025	4.1246 - 4.1274
6	Out of Round	Production	.0005 Max.		.001 Max.			
		Service	.002 Max.					
7	Taper	Production - Thrust Side	.0005 Max.					
		Production - Relief Side	.0005 Max.		.001 Max.			
		Service	.005 Max.					
	PISTON:							
8	Clearance	Production	.0005 -.0015	.0025 - .0031	.0012 - .0018		.0007 - .0013	.0018 - .0026
		Service	.0025 Max.	.0045 Max.	.0032 Max.		.0027 Max.	.0045 Max.
	PISTON RING:							
9	COMPRESSION Clearance Groove	Production - Top	.0012 - .0027	.0020 - .0040	.0012 - .0027		.0012 - .0032	.0017 - .0032
		Production - 2nd	.0012 - .0032		.0012 - .0032			
		Service	Hi Limit Production + .001					
	COMPRESSION Gap	Production - Top	.010 - .020					
		Production - 2nd	.010 - .020				.013 - .025	.010 - .020
		Service	Hi Limit Production + .01					
	OIL Groove Clearance	Production	.005 Max.	.005 - .0055	.005 Max.		.002 - .007	.0005 - .0065
		Service	Hi Limit Production +.001					
	OIL Gap	Production	.015 - .055					.010 - .030
		Service	Hi Limit Production + .01					
	PISTON PIN:							
	Diameter		.9270 - .9273					.9895 - .9898
10	Clearance	Production	.00015 - .00025					.00025 - .00035
		Service	.001 (Max.)					
	Fit in Rod		.0008"-.0016 Interference					
	CRANKSHAFT:							
11	Main Journal Diameter		All 2.2983 - 2.2993		#1-2-3-4 2.4484 - 2.4493			#1-2 2.7487 - 2.7496
					#5 2.4479 - 2.4488			#3-4 2.7481 - 2.7490
								#5 2.7473 - 2.7483
	Main Journal Taper	Production	.0002 (Max.)					
		Service	.001 (Max.)					
	Main Journal Out of Round	Production	.0002 (Max.)					
		Service	.001 (Max.)					
12	Main Bearing Clearance	Production	All .0003 - .0029	All .0008 - .0034	#1 .0008 - .0020			#1 .0007 - .0019
					#2-3-4 .0011 - .0023			#2-3-4 .0013 - .0025
					#5 .0017 - .0033			#5 .0019 - .0033
		Service	#1 - .002 (Max.) All Others .0035 (Max.)					
	Crankshaft End Play		.002 - .006					.006 - .010
13	Crankpin Diameter		1.999 - 1.2000	2.099 - 2.100	2.199 - 2.200			2.1985 - 2.1995
	Crankpin Taper	Production	.0003 (Max.)					
		Service	.001 (Max.)					
	Crankpin Out of Round	Production	.0002 (Max.)					
		Service	.001 (Max.)					
	Rod Bearing Clearance	Production	.0007 - .0027		.0013 - .0035			.0009 - .0025
		Service	.0035 (Max.)					
	Rod Side Clearance		.0009 - .0014		.008 - .014			.013 - .023
	CAMSHAFT:							
14	Lobe Lift ± .002"	Intake	.2217	.2315	.2800			.2343
		Exhaust	.2217	.2315	.2733			.2343
	Journal Diameter		1.8682 - 1.8692					1.9482 - 1.9492
	Camshaft Runout		.0015 Max.					
	VALVE SYSTEM:							
	Lifter		Hydraulic					
	Rocker Arm Ratio		1.75:1		1.50:1			1.70:1
15	Valve Lash	Intake	One Turn Down From Zero Lash					
		Exhaust						
16	Face Angle (Int. & Exh.)		45°					
	Seat Angle (Int. & Exh.)		46°					
	Seat Runout (Int. & Exh.)		.002 (Max.)					
17	Seat Width	Intake	1/32 -1/16					
		Exhaust	1/16 -3/32					
18	Stem Clearance	Production - Int.	.0010 - .0027					
		Production - Exh.	.0015 - .0032		.0010 - .0027			.0012 - .0029
		Service	Hi Limit Production +.001 Intake - +.002 Exhaust					
19	Valve Spring (Outer)	Free Length	1.90		2.03			2.12
		Pressure lbs. @ in. Closed	55-64 @ 1.66	85-93 @ 1.69	76-84 @ 1.70			69-81 @ 1.88
		Pressure lbs. @ in. Open	180-192 @ 1.27	174-184 @ 1.30	194-206 @ 1.25			228-252 @ 1.38
		Installed Height ± 1/32"	1-21/32	1-5/8	1-23/32			1-7/8
	Valve Spring (Inner)	Free Length	—					2.06
		Pressure lbs. @ in. Closed	—					26-34 @ 1.78
		Pressure lbs. @ in. Open	—					81-99 @ 1.28
		Installed Height ± 1/32"	—					1-25/32
	Damper	Free Length	—	1.94				—
		Approx. # of Coils	—	4				—

TUNE-UP SPECIFICATIONS

ENGINE AND CODE (Code is on Oil Filler Pipe V-8)	IGNITION TIMING L-6 33° DWELL V-8 30° DWELL	SPARK PLUG TYPE & GAP	SOLENOID SCREW † (RPM)	SLOW IDLE CARBURETOR SCREW (RPM)♦	▲ FAST IDLE RPM	CARBURETOR IDENTIFICATION 7043	EMISSION CONTROL DEVICES	EGR VALVE MODEL	TUNE-UP LABEL CODE	SPARK DELAY DEVICE	DISTRIBUTOR DISTRIBUTOR MODEL	DISTRIBUTOR VACUUM MODEL	VACUUM AND MECHANICAL ADVANCE VACUUM ADVANCE @INCHES OF VACUUM	VACUUM AND MECHANICAL ADVANCE MECHANICAL ADVANCE @DISTRIBUTOR RPM
250 CU. IN. 1 BBL. L-6 ENG. CODES (L-22) CCC, (CCD CALIF) M.T. CCA, (CCB CALIF) A.T. OMEGA	6° @ 700	R46TS .035" GAP	700 (N)	*450 (N)	PRESET	017 (MT)	C.E.C., C.C.S. P.C.V. A.I.R., E.G.R.	7035171	WB	NO	1110499	1973428	START 6-8 IN. HG. 12° 14.5-15.5 IN. HG.	0° 930 RPM 2° 1270 RPM 14° 2300 RPM
	6° @ 600	.035" GAP R46TS	600 (DR)	*450 (PARK)	PRESET	014 (A.T.)	A.I.R., E.G.R. C.C.S. P.C.V.	7035169		NO				24° 4100 RPM
350 CU. IN. 2BBL. V-8 ENG. CODES (L-32 A.T.) QP, QQ, QS, QT OMEGA & CUTLASS	14° @ 1100	R46S .040" GAP	700 (DR)	550 (PARK)	900 (PARK)	• 158 OMEGA • 154 CUTLASS	C.C.S., E.G.R. T.V.S. P.C.V.	7040497	OA	NO	1112226	1973468	START 3.5-4.5 IN. HG. 10° 12-13 IN. HG.	0°-2° 400 RPM 8°-10° 1050 RPM 14°-16° 2000 RPM
350 CU. IN. 2BBL. V-8 ENG. CODES (L-33 A.T.) QN, QO 88	12° @ 1100	R46S .040" GAP	700 (DR)	550 (PARK)	900 (PARK)	• 152	C.C.S., E.G.R. T.V.S. P.C.V.	7040452	OB	NO	1112226	1973468	START 3.5-4.5 IN. HG. 10° 12-13 IN. HG.	0°-2° 400 RPM 8°-10° 1050 RPM 14°-16° 2000 RPM
350 CU. IN. 4BBL. V-8 ENG. CODES (L-34 EXC. WGN. A.T.) QA, QB, QJ, QK OMEGA & CUTLASS	12° @ 1100	R46S .040" GAP	650 (DR)	550 (PARK)	1000 (PARK)	• 255 OMEGA • 250 CUTLASS	C.C.S., E.G.R. T.V.S. P.C.V.	7040452	OC	YES "V"	1112195	1973453	START 5-7 IN. HG. 8° 10-12 IN. HG.	0°-2° 400 RPM 8°-10° 1050 RPM 14°-16° 2000 RPM
350 CU. IN. 4BBL. V-8 ENG. CODES (L-34 WGN. A.T.) QU, QV VISTA CRUISER	10° @ 1100	R46S .040" GAP	650 (DR)	550 (PARK)	1000 (PARK)	• 256	C.C.S., E.G.R. T.V.S. P.C.V.	7030963	OP	YES "V"	1112225	1973453	START 5-7 IN. HG. 8 10-12 IN. HG.	0°-2° 380 RPM 5°-7° 550 RPM 11°-13° 1050 RPM 17°-19° 2000 RPM
350 CU. IN. 4BBL. V-8 ENG. CODES (L-34 M.T.) OMEGA, QC, QD, QE, QL CUTLASS & V.C.	8° @ 1100	R45S .040" GAP	1100 (N)	650 (N)	1100 (N)	• 255 OMEGA • 257 CUTLASS	C.C.S., E.G.R. T.V.S. P.C.V.	7040350 V.C. 7040528	OM	NO	1112222	1973453	START 5-7 IN. HG. 8° 10-12 IN. HG.	0°-2° 485 RPM 8°-11° 1000 RPM 14°-16° 2000 RPM
455 CU. IN. 4BBL. V-8 ENG. CODES (L-75 M.T.) UD CUTLASS	10° @ 1100	R45S .040" GAP	1000 (N)	750 (N)	1100 (N)	• 253	C.C.S., E.G.R. T.V.S. P.C.V.	7040350	OJ	YES "V"	1112197	1973232	START 7-9 IN. HG. 9° 15-16.6 IN. HG.	0°-2° 540 RPM 5°-7° 1000 RPM 9°-11° 1800 RPM
455 CU. IN. 4BBL. V-8 (L-74 & L-75) ENG. CODES UA, UB, US, UT (A.T.) CUTLASS, 88 & 98	8° @ 1100	R46S .040" GAP	650 (DR)	550 (PARK)	1000 (PARK)	• 251	C.C.S., E.G.R. T.V.S. P.C.V.	7040452	OD	YES "V"	1112197	1973232	START 7-9 IN. HG. 9° 15-16.6 IN. HG.	0°-2° 540 RPM 5°-7° 1000 RPM 9°-11° 1800 RPM
455 CU. IN. 4BBL. V-8 ENG. CODES (L-78 A.T.) UU, UV TORONADO	8° @ 1100	R46S .040" GAP	650 (DR)	550 (PARK)	1000 (PARK)	* 252	C.C.S., E.G.R. T.V.S. P.C.V.	7040452	OS	YES "V"	1112198	1973466	START 7-9 IN. HG. 9° 12-14 IN. HG.	0°-2° 575 RPM 3.5°-5.5° 1000 RPM 7°-9° 1700 RPM

C.E.C. = Combined Emission Control Valve
A.I.R. = Air Injection Reactor
E.G.R. = Exhaust Gas Recirculation
C.C.S. = Controlled Combustion System
T.V.S. = Thermal Vacuum Switch
P.C.V. = Positive Crankcase Ventilation

† Turn Idle Stop Solenoid In or Out To Adjust Slow Idle RPM (Solenoid Energized)
* Turn 1/8" Hex Screw To Adjust Low (Shutoff) Idle. (Solenoid De-Energized)
▲ With E.G.R. Vacuum Hose Removed and Plugged
♦Solenoid De-Energized
V =Vacuum Device
•Choke Set At Index
*Choke Set One Notch Rich



OP
GM 301
350 CU. IN.
4 BBL. CARB.

VEHICLE EMISSION CONTROL INFORMATION
OLDSMOBILE DIVISION • GENERAL MOTORS CORP.

MAKE ADJUSTMENTS WITH ENGINE AT NORMAL OPERATING TEMPERATURE, CHOKE OPEN AND AIR CONDITIONING OFF. PLUG DISCONNECTED VACUUM FITTINGS AND/OR HOSES.
SET PARKING BRAKE AND BLOCK DRIVE WHEELS.

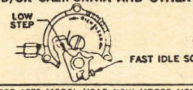
1. DISCONNECT AND PLUG CARB. HOSES FROM VAPOR CANISTER, E.G.R. VALVE AND DISTR. VACUUM UNIT.
2. SET DWELL. SET TIMING AT SPECIFIED RPM.
3. ADJUST SOLENOID (ENERGIZED) SCREW TO SPECIFIED RPM.
4. ADJUST CARBURETOR SPEED SCREW (SOLENOID DE-ENERGIZED) TO SPECIFIED RPM.
5. WITH TRANSMISSION IN PARK ADJUST FAST IDLE SCREW TO SPECIFIED RPM ON LOW STEP OF CAM (NO E.G.R.)
6. RECONNECT DISTR., CANISTER AND E.G.R. VALVE HOSES.

SEE OLDSMOBILE SERVICE MANUAL FOR ADDITIONAL INFORMATION
FUEL REQUIREMENTS—USE 91 OCTANE OR HIGHER
THIS LABEL USED WITH ENGINE CODE: QU • QV

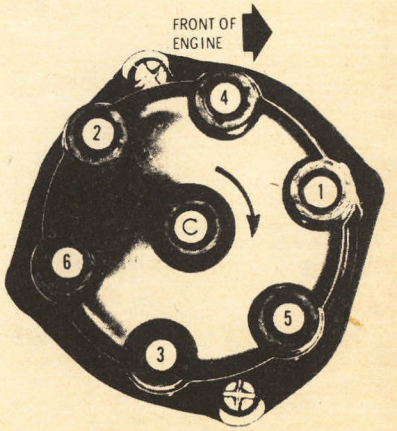
C.C.S. — E.G.R.
EXHAUST EMISSION CONTROL

DWELL	30°
TIMING (DEG. BTDC @ RPM)	10° @ 1100
SPARK PLUGS GAP TYPE	.040" AC R 46 S
SOLENOID SCREW (RPM)	650 (IN DRIVE)
CARBURETOR SCREW (RPM)	550 (IN PARK)
FAST IDLE SCREW (RPM)	1000 (IN PARK)
CHOKE SETTING	INDEX

IDLE MIXTURE PRESET—DO NOT REMOVE CAPS.
IF CARBURETOR IS REPAIRED AND IDLE EXCEEDS 1% CO, RESET IDLE TO .3% CO.
REMOVAL OF MIXTURE CAPS AND ALTERING TO OTHER THAN SPECIFIED CO SETTING MAY VIOLATE FEDERAL AND/OR CALIFORNIA AND OTHER STATE LAWS.



PRINTED IN U.S.A.
THIS VEHICLE CONFORMS TO U.S. EPA AND WHERE APPLICABLE, CALIFORNIA REGULATIONS FOR 1973 MODEL YEAR NEW MOTOR VEHICLES. Part No.414321

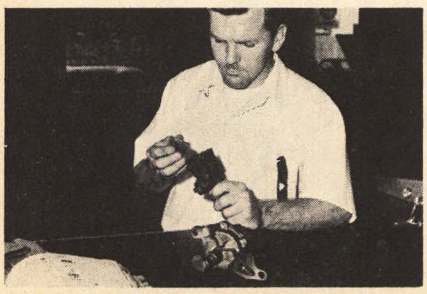


Where to Get Parts

The buying of parts for an automobile is considerably different now than it was way back when. In the old days, mechanics used to fix things. Wages were very low—perhaps as low as $2 or $3 a day in some cases. From both a time and money standpoint, it was practical to remove a unit from a car, give it to a mechanic and let him spend several hours tearing it apart, replacing the small piece that had broken or worn out, and then reassembling the unit. With the rise in wages, to the point where shop time in some garages now costs as much as $15 an hour, it just isn't practical to pay a mechanic to fix anything. Now, most of the fixing is done on an assembly line in some factory. The repaired or rebuilt units are furnished to repair garages, and all the mechanic does is make a replacement.

In many cases, this replacement philosophy applies to new parts also. Assembly lines are so efficient nowadays that new parts can be built almost as cheaply as the rebuilder can renew an old part. The result is that there is a definite competition between new and rebuilt parts, with new parts frequently coming out the winner, because their cost is very close to that of a rebuilt item.

The replace-instead-of-repair situation can be exasperating to a competent home mechanic. He knows what part is worn out inside the unit he wants to fix, but he can't buy it at the parts house, and is therefore forced to buy the complete unit, spending much more money than he would have spent if he could obtain the individual parts. The replacement philosophy has gone so far that some units are not rebuildable under any circumstances. Most of the late fuel pumps, for example, are sealed. You can't even take them apart. When one goes bad, you throw it away and put on a new one. For that reason, we have not shown in this book how to rebuild certain parts such as a water pump, because we know that it is extremely difficult to find water pump rebuilding kits nowadays. You are forced to replace the worn-out pump with either a rebuilt or a new one.

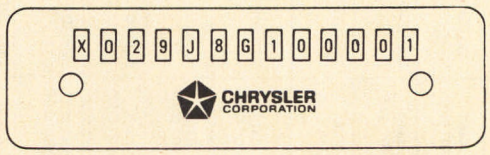


2. Double-Checking New Parts

We'll get into the advantages and disadvantages of new versus rebuilt parts a little later, but this list of rebuilt items in order of sales popularity will give you an idea of what commercial garages have found practical to replace as an assembly rather than overhaul themselves: generators, starters, brake shoes, fuel pumps, clutch pressure plates, clutch discs, starter drives, water pumps, carburetors, connecting rods, armatures, crankshafts, complete engines, solenoids, voltage regulators, power brake parts, oil pumps, brake cylinders, shock absorbers and transmissions. This order of popularity is an indication of both the frequency of failure and the degree of difficulty in making individual repairs. The latter is not so much a measure of complexity but the type of assembly required: *e.g.*, a generator or alternator has many parts that are soldered or glued together and thus lends itself to production line rebuilding.

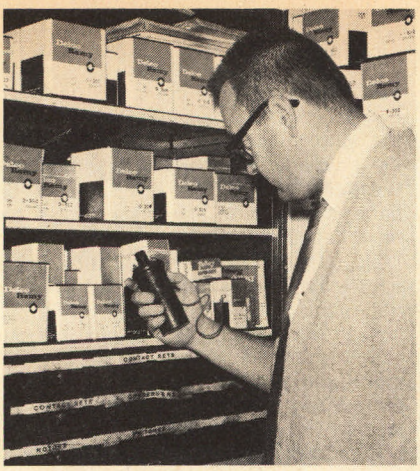
The main sources for parts are new-car dealers and automotive parts houses (jobbers). If you go to the dealer you will only be able to buy parts for his make of car, whereas the jobber has parts for all makes. However, there are parts called dealer items that have such a narrow application that the jobber doesn't carry them. They are available only from the dealer.

1. Buying Specialty Parts

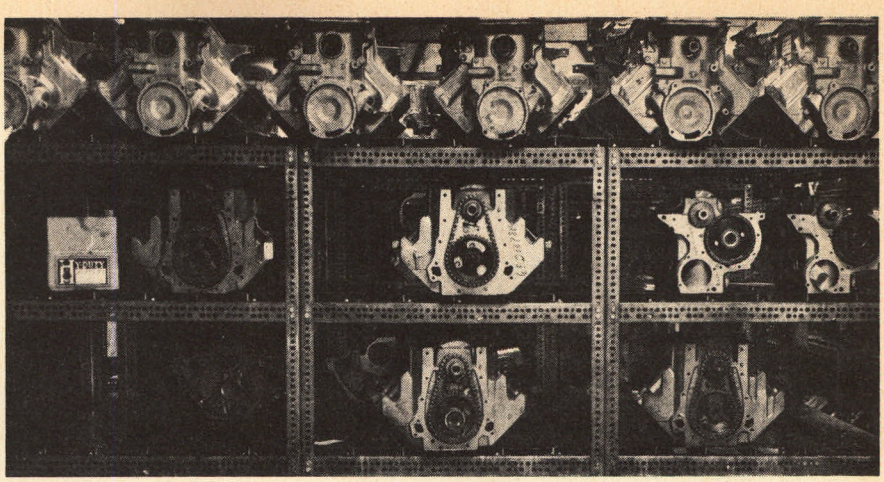


1st Digit	2nd Digit	3rd & 4th Digit	5th Digit	6th Digit	7th Digit
Car Make	Model	Body Style	Engine Ident. Displacement	Year	Assembly Plant
L—Dart	L—Low	21—2 Door Sedan	A—170 Cu. In.	8-1968	A—Lynch Road
	H—High	23—2 Door Hardtop	B—225 Cu. In.		B—Hamtramck
W—Coronet	M—Medium	27—Convertible	C—Spec. (6 cyl.)		C—Jefferson
	P—Premium	29—Charger	D—273 Cu. In. Std.		D—Belvidere
X—Charger	K—Police	41—4 Door Sedan	F—318 Cu. In. Std.		E—Los Angeles
	T—Taxi	43—4 Door Hardtop	G—383 Cu. In. Std.		F—Newark
	S—Special	45—6 Pass. Sta. Wgn.	H—383 Cu. In. H.P.		G—St. Louis
	O—Super Stock	46—9 Pass. Sta. Wgn.	J—426 Cu. In. Hemi		R—Windsor
			K—440 Cu. In. Std.		
			L—440 Cu. In. H.P.		
			M—Spec. (8 cyl.)		
			P—340 Cu. In.		

3. Typical Identification Plate Code



4. Buying Original Equipment Parts



5. Remanufactured Engines

Besides dealers and jobbers, there are many other sources for parts. General automotive stores, hardware stores, department stores, wrecking yards, and mail order companies are all good sources, but none of them has the complete selection carried by the dealer or the jobber.

If a week or so's delay in obtaining the needed part won't inconvenience you, a very practical source for quality merchandise is to order it by mail or by phone from the nearest catalog order center operated by Sears, Ward or Spiegel. Sears has a special automotive catalog available free for the asking. Then, J. C. Whitney and Honest Charley have extensive catalogs listing replacement parts as well as hot rod items.

IDENTIFYING THE PART

If you bought your car new, you of course know its specifications in detail or at least they will be listed on your copy of the order form, if you still have it. Detailed information, however, will generally be missing in most used car transactions. You will know the model designation, year, the fact that it's a V-8 or not and whether or not it is equipped with an automatic transmission. Still, this is not enough information upon which to base the purchase of many parts. For example, a 361-in. V-8 was standard in Chrysler Newports of the early '60's, but a 383-in. V-8, identical in outward appearance and dimensions, was optional. Current MoPar twins include the 318- and 340-in. V-8's used in many Plymouth and Dodge models. Similar situations exist in GM divisions, FoMoCo and American Motors. Obviously, many internal parts are not interchangeable on these engines because the bore and stroke differ. These factors, in turn, may or may not dictate differences in fuel, ignition and drivetrain components. Lastly, since auto makers don't like to rely on a single source of supply for a component they may, like Ford, make some of their own carburetors and buy the rest of their requirements on the outside, in this case Holley. On a given model, these units are generally interchangeable as an assembly but their components are different and cannot be interchanged.

1. Specialty parts dealers can often provide items for specialized applications which may not be readily available from general parts houses, dealerships, mail order firms, etc. Selection, immediate availability and guarantee are prime considerations in selecting a parts source.

2. Precise identification of specific parts to fit particular system components is often best done by taking the old unit to the parts-buying source for a direct double-check.

3. Detailed description of a car model and its engine is necessary for identifying the specific item being sought. Chrysler Corp. identification plate code will list the car series, model, body style, engine, year of manufacture, assembly plant.

4. Original equipment replacement parts can be bought at independent parts stores as well as car dealers. They're often preferred by car owners who like "brand-name" reassurance.

5. New or rebuilt engines can be purchased through new car agencies and garages, and sometimes parts houses. Better companies will usually offer a warranty, something that's lacking in a wrecking yard "as is" deal.

DEFINING YOUR CAR

All auto makers, past and present, have permanently affixed to the vehicle one or more sets of code numbers that together define exactly the specifications and major items of optional equipment that were included when it was built. Changes made by the original or subsequent owners will not be reflected in these codes. Sometimes decoding information is included in the owner's manual; in all cases it will be found in the first few pages of the applicable shop manual that is available for purchase at prices ranging from $5 to $10 directly from the factory. Information on how to order these manuals (they are available for older cars) is available at the new car dealer, and it's worth noting here that you can make the best use of the book you are now reading by supplementing it with the specific information contained in the shop manual for your make and model.

Coding systems used vary from make to make, and sometimes within a make, from year to year. On some models the plate is located on the dash panel in the left corner where it is visible through the windshield. On others, you'll find it on the left front door post or on the firewall. On a 1968 Dodge with the number XO29J8G-100001, the first digit is a letter that defines the make, the letter "X" in this instance standing for Charger. The second digit indicates various degrees of luxury, performance or special usage. The sample shows "O" which stands for Super Stock, an important bit of information because that designation indicates the presence of special equipment packages such as heavy-duty suspension, cooling and powertrain systems. The table shows how this second letter is coded in no particular order of the alphabet.

Low through Premium ("L" and "P," respectively) are indications of trim luxury and the rest, special purpose designations. The third and fourth digits tell body style. Note that our sample Charger carries a different number than the standard 2-door hardtop. The fifth digit is a letter code for engine type and displacement, the "J" in our sample standing for the 426-in. Hemi. Next comes the number "8" to indicate the model year, 1968. Finally, the seventh digit shows the assembly location, an item unimportant to the owner except if our sample had shown "R" for Windsor, Ontario, Canada. Many of the auto makers have Canadian assembly plants, and a Canadian-built car may contain parts that vary in detail from their U.S. equivalents. However, Super Stock Chargers aren't assembled there so our completed identification plate reads "X O 2 9 J 8 G—100001." These last six numbers would indicate that you own the first 1968 Charger built. This sample identification, incidentally, would also be the one used for licensing purposes in most states.

Even with this relatively complete system used by Dodge, there is still quite a bit of information missing. Some of it will be found on an auxiliary body-number plate located, in the case of our sample Charger, on the left front wheel house. These codes, too, vary from make to make, but the system currently used by Dodge is indicated as an example.

If you know how to interpret the identification code for your car, you'll be

Where to Get Parts

able to order parts for it with accuracy. This assumes, of course, that you can accurately describe the function of the needed part to the counterman or better yet, bring the old one with you for positive identification.

PART NOMENCLATURE

The average modern car contains about 15,000 separate parts, and at a given time anywhere from 50% to 75% of these will have application on previous models, depending upon whether it is the policy of that auto maker to make frequent engineering and/or styling changes. Chevrolet, for example, revises its cars in more detail from year to year than does American Motors. There is also a considerable degree of joint usage between makes made by the same parent company.

Internal body parts, transmissions, differentials and suspension components are all widely shared. The parts with a specific application to a single line are usually identification features such as trim, external body panels, instruments and the like.

Ford, Chrysler and American Motors catalog and sell parts on a corporate basis. Thus, any part shared by Ford and Mercury would carry the same number at both dealerships, and the same would be true of Dodge and Chrysler-Plymouth. General Motors, however, is somewhat more complicated. Except for internal body components and in a few isolated instances, engines and transmissions, there is far less sharing between divisions. And when they do, the part numbers will be different. For example, both Buick and Oldsmobile have offered a Chevrolet-built L-6 engine in their low-line intermediates, but every part in this engine carries a Buick or Oldsmobile part number as well as a Chevrolet number, depending upon the make of car in which it is installed. GM accessory divisions such as United-Delco and Harrison Radiator, on the other hand, carry their own specific part number, regardless of interchangeability.

There once was a day when a certain model Carter carburetor or Bower bearing would fit in a dozen different makes of cars. An interchange manual was worth its weight in diamonds, and "The Hollander" was the one to have.

Nowadays such easy interchangeability doesn't exist, but there is still enough similarity between parts that the Hollander manual is a good tool to own. It costs $43.50, covers U.S. cars from '61-'71, and is available from Hollander Publishing Co., 12320 Wayzata Blvd., Minnetonka, Minn. 55343. The Hollander's primary use is in wrecking yards, where a sale might be lost if the counterman didn't know that a certain Chevrolet part will also fit a Pontiac. For car nuts who just want to have a Hollander, the publisher has older editions for a lower price.

You can see now why you just can't go down to the dealer, much less the independent jobber, and ask for a "widget that fits on the whats-it" for your 1967 Chevy. You have to say "I need an automatic choke temperature sensing unit for the 4-bbl. Rochester on my 1967/SS-396 to replace the old one I have here that's stamped part No. 000001." The counterman will still consult one of his catalogs because he might have to say, "There's been a running change on that part. I'll give you part No. 000002 which will fit right in if you use this adapter No. 10000001, and you should have no more trouble." An independent jobber, selling non-official replacements, may or may not know of this change. Be as specific as you can to save both your time and that of the counterman.

WHERE TO BUY PARTS

As we have mentioned earlier, the main sources for automotive parts are the car dealer, the independent jobber, the automotive chain store, the mail order house and the wrecking yard. These are not listed in order of preference because there are advantages and disadvantages with each source.

No rule can be made in choosing between the car dealer or a jobber as a parts source. The car dealer is the only source for some parts. Jobbers and other outlets compete with the dealer in the marketplace. You should consider all outlets for parts and buy wherever you find satisfaction.

Of course, if you own a car that is no longer manufactured, like a Studebaker or Kaiser, the jobber and mail order house are your only sources for new parts. Many people think there is a law requiring auto companies to make parts available for a certain number of years after they discontinue a model or go out of business. There is no such law. The left-over parts are bought up by brokers strictly on the basis of how many Kaisers, Edsels, Studebakers or whatever are still on the road and as long as there is a demand, there will be a supply through jobber and mail order channels. Sometimes this demand causes a car to be in a sense, reborn. You can, for example, practically assemble a brand new Model "T" or "A" Ford from the catalogs of Sears or J. C. Whitney, though it's doubtful that any part would be available for these cars at a Ford dealership.

Chain stores like the Pep Boys, Western Auto, J. C. Penney or the auto departments at Sears and Ward retail stores generally limit their replacement parts stock to fast moving items like plugs, points, fan belts, perhaps a few varieties of voltage regulators and horn relays, and anything that has a universal fit like sealed-beam headlight units.

1. Parts at Swap Meet

Mail order, as we've said, takes a little time but is an entirely satisfactory way of buying parts. The Sears, Ward, Spiegel, J. C. Whitney and Honest Charley catalogs are amazingly complete; all of them stock parts for a wide variety of imported cars. A further advantage is that these firms "guarantee satisfaction or your money back," a protection that may or may not exist when dealing with a car dealer or jobber.

Address requests for automotive catalogs to:

Sears Roebuck and Co.
Local catalog order center

Montgomery Ward and Co.
Local catalog order center

Spiegel Inc.
Chicago, Illinois 60609

J. C. Whitney & Co.
1917 Archer Ave.
Chicago, Illinois 60616

Honest Charley Inc.
108 Honest St.
(P.O. Box 8535)
Chattanooga, Tenn. 37411

NEW VS. REBUILT PARTS

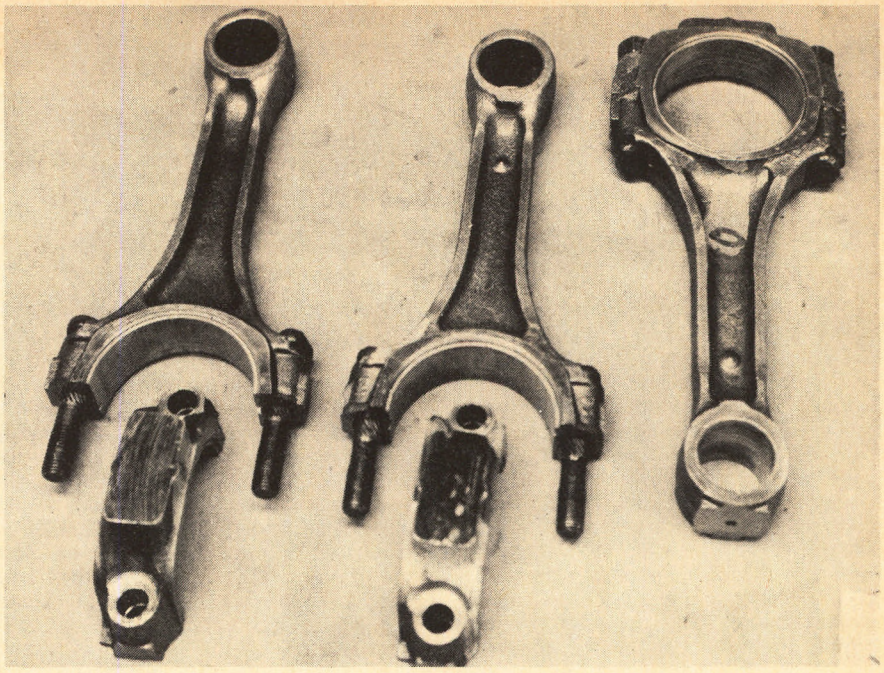
You can get into some heated arguments over which is better—a brand-new part or one that has been rebuilt or has been reconditioned. The quality of any automotive unit depends upon the inspection procedures that are supposed to eliminate all the faulty parts. There isn't a machine or a man that is perfect. No matter how hard a manufacturer or a rebuilder tries, a certain percentage of the parts he has on hand will be defective. Most of the defective parts will be eliminated by inspection, but some of them will definitely turn up in completely assembled units at the end of his assembly line. The manufacturer and rebuilder know this, so they perform tests on the completed units to weed out the bad apples. The big question is: Do they test every unit, 1 out of 10, or 1 out of 100, or none? There are some manufacturers who don't look at anything after it comes off the end of the line. They figure that if it's bad enough, the ultimate user—you and I—will bring it back to the store where he bought it, and either get his money back or get another part. Fortunately, there are not many rebuilders or manufacturers with that attitude. The only way you can protect yourself from such fast buck artists is by relying on your own experience and the experience of other people who have purchased parts. If a mechanic tells you that he has had bad luck with a certain brand of either new or rebuilt parts, then by all means stay away from that brand.

You should also listen to a mechanic's recommendation for good parts. Some shops have been using a certain line of new or rebuilt merchandise for many years with a very low comeback rate. Those are the parts that you should use on your car.

If there is no one from whom you can get advice, then the safest way to go is to use what are known as "original equipment" parts. The theory behind using original equipment parts is that if the car maker thought the parts were good enough for him, then they certainly should be good enough for you and me as replacements. Examples of original equipment parts would be Delco-Remy electric parts and units on General Motors cars, Autolite electrical units on Ford products, and Holley carburetor parts on Holley carburetors. In many cases, it is not necessary to go to the new car dealer to get your original equipment parts. Most of the parts manufacturers who supply the original equipment units to the car maker and his dealers also sell through independent parts stores. For example, all General Motors cars are equipped with AC fuel system parts, but you can buy AC units at almost any auto parts store.

1. For that unusual part needed for a scratch-built model or a restoration job, a swap meet may very well turn up some hard-to-find items.

2. With the high degree of interchangeability built into many factory parts, it is often possible to substitute a heavy-duty part for a stock item when making repairs—if you know the correct part numbers. Shown here are three kinds of rods for big-block Chevy engines (from left): standard, high-performance, and "super" high-performance.



2. Different Types of Rods

THE ROLE OF THE WRECKING YARD

Members of the National Auto and Truck Wreckers Association (NATWA) don't like to be referred to as operators of junkyards. Their main function today is to supply the nation's steel mills with the 50% content of scrap steel needed to blend with the fresh pig iron in each charge of the furnace. In addition, about 70 lbs. of aluminum, 35 lbs. of copper, 30 lbs. of zinc, 20 lbs. of lead and 180 lbs. of rubber are similarly salvaged from each wreck, new or old, and ultimately reused.

All yard operators strip some fast-moving or valuable parts from a wreck and stock them for resale. Examples would be undamaged components from an air-conditioning system; batteries, tires and even engines and transmissions from late-model wrecks; and intact sheetmetal parts like hoods, trunk lids, bumpers and grilles. The biggest operators are tied together by a regional teletype system so that if one doesn't have the part, it can be determined in seconds whether anybody has it. In fact, if your needs are put on teletype and no one has the part, odds are that in a few days an accident will happen that will enable your order to be filled. A late-model wreck, totalled from an insurance standpoint, is by no means "junk." It will return at least $500 if properly salvaged. Then, there are still countless rural yards that fill a cow pasture with derelict cars and let you prowl around until you find the part you want. These are self-service stores in the true sense because you do your own dismantling, but it's a fascinating way to spend a Saturday afternoon.

The yards that cater to retail customers will generally be quite obvious because there will be a building to house the binned and inventoried small parts and outdoor display racks for the larger items. You must remember, though, that while the part may look serviceable, there is no guarantee that it is, because the yard operator, with the sometime exception of complete engines, doesn't check their function. Therefore, if you wanted to replace a damaged radiator on your late-model car, go search the yards for a low-mileage identical model that's been totalled from the rear. For older cars, the salvage radiator may be no better than the one you want to replace. The bigger yards know what they can get for an item so there is no sense in haggling. In the do-it-yourself lots, though, start with an offer.

Lubrication

Nobody, except perhaps a small boy, finds any particular pleasure in getting dirty. It isn't so bad if only your hands get dirty when working on your car, but when you get grease on your shoulders and in your hair and maybe down the middle of your back from crawling around underneath while doing a grease job, it's no wonder that most lube jobs are done in service stations while the owner just stands and watches. Paying somebody else to do your oil changes and lubrication can be expensive—not only because you are paying for their labor, but because you are giving them full price or even more for the oil and other parts that they use. A good lever-type grease gun can be purchased from Sears or Ward for a few dollars, and almost all discount stores have greases and oils. If you don't mind a distasteful job, you can save quite a bit of money by doing the oil changes and lube jobs yourself.

Lubrication and general maintenance work should be performed on a "mileage" or "time" basis. Either one or both can be utilized according to driving habits. Simply put, if you don't drive enough miles within a certain time period, say 90 days, the service should still be performed to keep your car in top running condition.

In recent years, all of the automobile manufacturers have extended both time and mileage service intervals with much improved components—filters, corrosion-resistant coatings and permanently lubricated joints. However, due to the differing geographical conditions in the U.S. (cold, heat, dust, moisture), certain components need more frequent servicing than others. Keeping this in mind, you will want to adjust (for some items) the service interval suggested in the lubrication and maintenance chart to suit your car's needs. Trailer towing would also come under this adjustment. It is true that a careful lubrication and maintenance program—one that you stick to—will keep your car looking and running like new for many years.

ENGINE OIL TYPES

The type or grade of engine oil and the regularity of engine oil changes will affect engine operation, wear, and combustion chamber deposits. Oil viscosity will affect oil economy and ease of starting. Many people think that a higher viscosity oil, such as 30 wt. or 40 wt., is a "better" oil than 10 or 20 wt. The weight of the oil has nothing to do with its quality. All that the weight numbers indicate is the thickness or fluidity of the oil, from the extremely thin oils of 5 or 10 wt., up to 90 or 140 for gears, and on up to 200 wt. or beyond, which is so thick you can't pour it.

There are four harmful deposits which can form in the crankcase of an engine: sludge, varnish, moisture, and acids. The formation of these deposits largely depends on the quality of oil and the additives therein, and the type of driving conditions. They form under both high- and low-speed driving conditions, but generally form more rapidly in cold weather under short-trip or city traffic conditions. As far as motor oil is concerned, consider these as severe operating conditions.

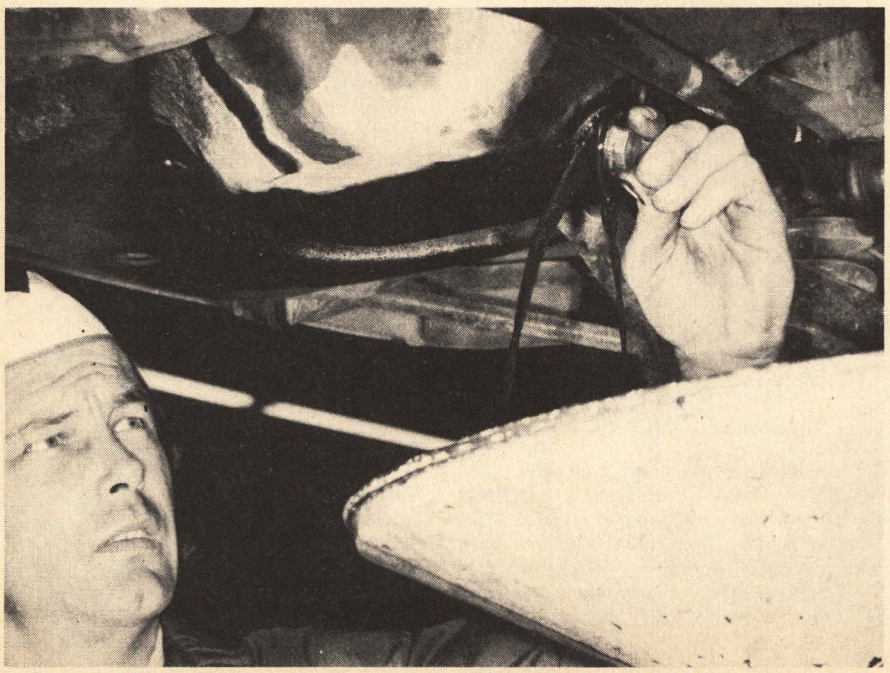
Formation of these deposits can be substantially reduced by using quality oils that contain the correct type and quantity of additives. Sludge is reduced by additives having detergent dispersing characteristics. Varnish deposits are reduced by oxidation inhibitors, and bearing corrosion is eliminated by corrosion-preventive additives.

To minimize the formation of these harmful deposits, and to assure the use of the oil best suited for present-day operating conditions, the automobile manufacturers have developed a series of sequence tests designed to evaluate the ability of any oil to properly lubricate automobile engines.

For many years, oils were graded ML, MM, or MS, for Motor Light, Medium, and Severe. MS was the best oil, because it would stand up under severe service, but it wasn't *the* best MS oil unless it had a statement on the can which verified that it had passed the car makers' sequence tests.

Now, there is a new rating system, with five classifications.

SA oils are non-detergent, with no performance requirements. This classification includes not only high-quality non-detergent oils put out by major companies, but also the dregs from the local



1. Removing Drain Plug

2. Cinching Down Filter

tar pit. If you want a good non-detergent oil, you will have to rely on the reputation of the maker.

SB oils have a few additives that protect against scuffing, bearing corrosion, and oil oxidation. These oils give only minimum protection.

SC oils are better. They have additives that protect against high- and low- temperature deposits, rust, wear, and corrosion.

SD oils are the next best. They protect against all the conditions that the other oils do, only more so. If a car maker recommends SC oil, you will be giving your engine greater protection by using SD oil.

Until late in 1971, SD oil was thought to be the best oil available, but then the strange cases of oil thickening showed up. It seems that increased engine temperatures caused by running lean to control emissions, when coupled with trailer towing or other heavy load operation at high speeds, can heat the oil so that it oxidizes, leaving nothing but a gooey mess that the oil pump can't pick up out of the pan. The result is a thoroughly destroyed crankshaft and bearings, maybe even a seized engine. To combat this, the oil makers have hurriedly come out with SE grade oil. It is now the best oil you can get, at least until some new problem comes up that it can't cope with.

Just in case you see them on the can, let's also go through the oil classifications for diesel use. The old classes were DG, DM, and DS, for Diesel General, Diesel Medium, and Diesel Severe. New diesel classifications are as follows:

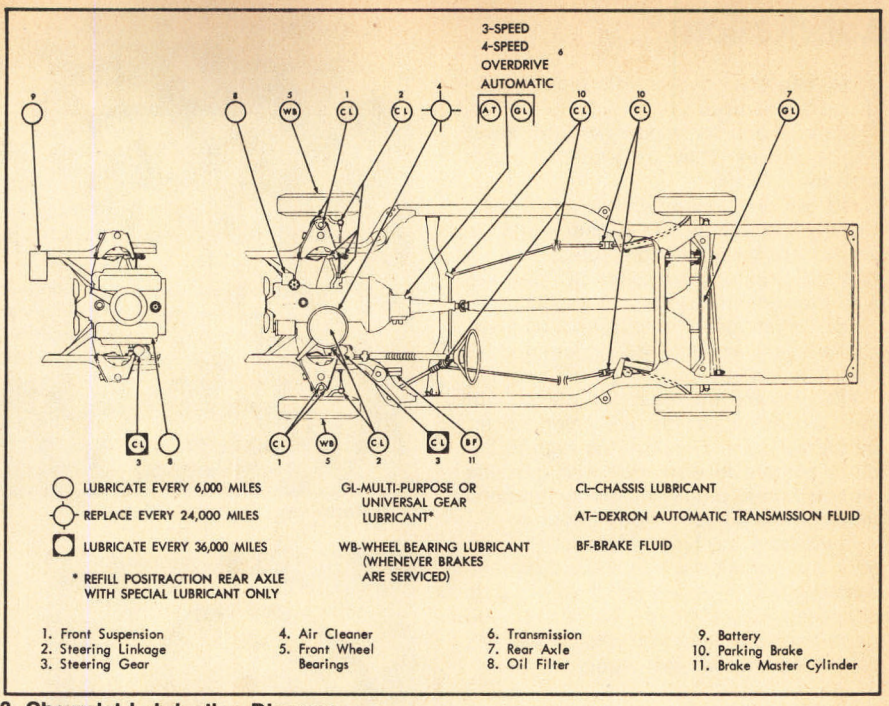
CA oils are for light-duty diesel engine service. These oils will give protection from bearing corrosion and high temper-

1. Your car represents a pretty healthy hunk of bread. Obviously it makes good "cents" to see that all of its moving parts are properly maintained and well lubricated. Most of us tend to sub out our maintenance work to keep our hands from getting dirty, but we can all save a considerable piece of change by investing in a few tools, some oil, grease and body lube—and do it ourselves.

2. There are several types of band wrenches and pliers available that are designed to loosen and tighten throwaway oil filters. Once the filter is in place, let the engine run until it reaches operating temperature. Then check around the edge. Tighten further if it leaks.

3. Chassis lubrication diagrams—such as for this '68 Chevy—can be found in any dealer's service manual. It allows the car's owner to see where the lubrication points are, the location of the oil and fluid reservoirs, and when they should be checked, refilled and/or replaced.

4. Lubrication is a matter of either mileage or time intervals. For example, if your car has seen 2 months or 2000 miles go by, it's time to lube the water pump, check the steering gear, change the oil and filter.



3. Chevrolet Lubrication Diagram

Quick-Reference Maintenance and Lubrication Guide

Months		2		6		12		24	36
SERVICE AT INDICATED TIME AND/OR MILEAGE INTERVALS — Mileage	Fuel Stop	2000	4000	5000	6000	10,000	12,000	24,000	36,000
Check engine oil level	X								
Check radiator coolant level (remove cap on cold engine only)	X								
Check battery liquid level	X								
Check windshield washer reservoir level	X								
Lubricate generator cup(s)		X							
Lubricate distributor cup		X							
Lubricate water pump(s) if equipped with grease fitting(s)		X							
Change engine oil and filter			X						
Check tire air pressure			X						
Lubricate front suspension on older types			X						
Lubricate exhaust manifold valve			X						
Check brake master cylinder fluid level			X						
Check hydraulic clutch master cylinder fluid level			X						
Check automatic transmission oil level			X						
Check power steering fluid reservoir			X						
Check steering gear lubricant level			X						
Clean and lubricate oil wetted wire mesh air cleaner[1]			X						
Clean and lubricate oil filler cap[1]			X						
Perform minor engine tune-up				X					
Check and clean crankcase ventilation system					X				
Check manual transmission lubricant level (early type)					X				
Check manual transmission lubricant level (full synchromesh type)							X		
Check rear axle lubricant level (early)					X				
Check rear axle lubricant level (late)								X	
Lubricate transmission, clutch and brake linkage					X				
Adust clutch pedal travel					X				
Lubricate universal joints with grease fittings					X				
Lubricate universal joints without grease fittings								X	
Perform brake adustment[2]					X				
Clean body and door drain holes					X				
Rotate tires					X				
Clean dry-type air cleaner[1]					X				
Replace dry-type air cleaner[1]							X		
Clean polyurethane type air cleaner[1]					X				
Perform body lubrication (hinges, striker plates, etc.)					X				
Inspect brake hoses					X				
Check accessory drive(s) belt tension					X				
Perform major engine tune-up						X			
Clean and refill oil bath type air cleaner[1]						X			
Clean and lubricate accelerator linkage						X			
Clean and repack front wheel bearings							X		
Lubricate dash controls and seat tracks							X		
Major brake adjustment (remove drums, clean dust, lube pivots, etc.)							X		
Check headlight adjustment							X		
Check front-end alignment[2]							X		
Clean battery terminals[2]							X		
Check air-conditioning system (bolts, hose condition, sight gauge)							X		
Replace P.C.V. valves and clean hoses							X		
Inspect cooling system[2]							X		
Lubricate slip yoke (automatic transmission models)							X		
Change automatic transmission fluid								X	
Check shock absorbers and bushings								X	
Replace spring leaf inserts (small pads between leaves)								X	
Check convertible top operation								X	
Lubricate speedometer cable								X	
Lubricate long-life front suspension									X

1 Perform this service more frequently in dusty areas 2 More frequently if necessary

NOTE: The above time and/or mileage servicing intervals are averages based on recommendations from various automotive sources, and are designed to serve primarily as a guide. Wherever possible, it is desirable to refer to specific car manufacturer shop manuals for factory-prescribed servicing intervals and procedures, particularly during warranty coverage periods. Unusual operating conditions—such as extreme heat or cold, extended trailer towing, dusty environment, excessive moisture, etc.—may demand more frequent servicing, which may also be the case with older, higher mileage cars.

4. Maintenance and Lubrication Guide

ature deposits, but only if high quality diesel fuel is used.

CB oils are for moderate-duty diesel engine service. They are a little bit better than the CA oils.

CC oils are a step better than CB oils. Lightly supercharged diesel engines should use these oils for protection from high temperature deposits. CC oils are also recommended in some gasoline engines. When used in gasoline engines, CC oils are roughly equivalent to SC classification oils.

CD oils are the best for diesel, but they are definitely not recommended for passenger cars. They are too high in additive content to work well with gasoline engine spark plugs. In diesel engines there are no plugs to worry about.

It will be some time before all the cartons and containers with the old grading system have disappeared. If your car is supposed to use SC or SD oil, but you can't find any, then you should use MS oil that has passed the sequence tests.

ENGINE OIL VISCOSITY

SAE oil viscosity numbers, we repeat, indicate only the viscosity or thickness of the oil and *do not* indicate other properties or quality.

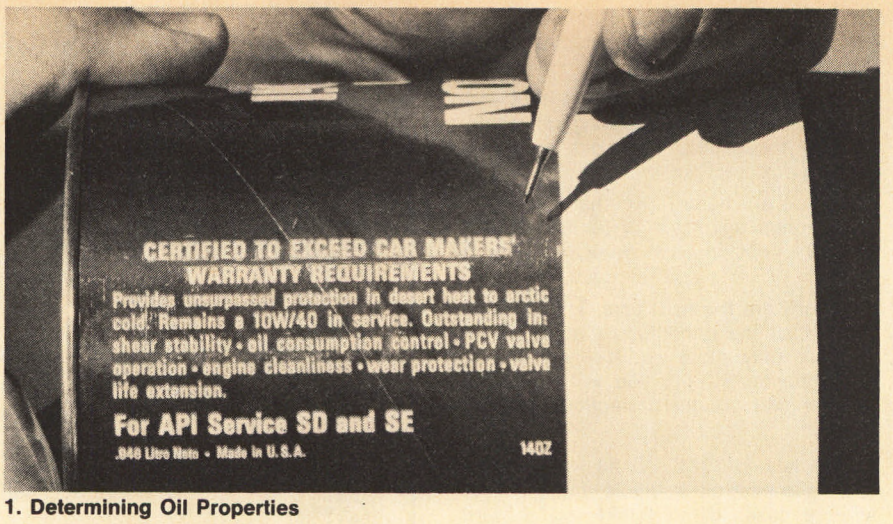
The lower SAE numbers, such as SAE 5W and SAE 10W (Winter), are light-body oils and are recommended for cold weather use. They provide easy starting and instant lubrication. The higher SAE viscosity numbers such as SAE 20, SAE 30, etc., are heavier-body oils and are recommended to provide adequate lubrication under high-operating-temperature conditions.

Oils are also available which are designed to combine the easy starting characteristics of the lower SAE numbers with the hot weather operating characteristics of the higher SAE numbers. These are called "multi-viscosity oils" and run SAE 5W-20, SAE 10W-20, SAE 10W-30, etc.

Engine oil should be selected to give the best performance under the climatic and driving conditions in the area in which your car is driven. When the crankcase is drained and refilled, the new engine oil should be selected not on the basis of the existing temperature at the time of the oil change, but on the lowest temperature anticipated for the period during which the oil will be used. The following chart will serve as a guide for the selection of the correct SAE viscosity numbers under different atmospheric conditions.

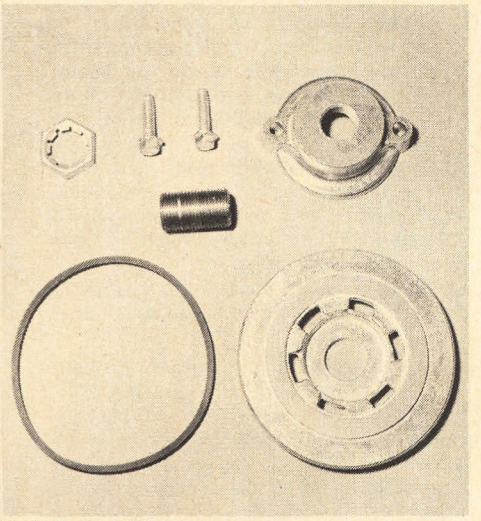
Lowest anticipated temperature	Recommended SAE viscosity	Recommended SAE multi-viscosity
Consistently above 32°F.	SAE 30 or 40	SAE 10W-30 or SAE 20W-40
0°F. to 32°F.	SAE 10W or SAE 20W	SAE 10W-30 or SAE 10W-40
Below 0°F.	SAE 5W or SAE 10W	SAE 5W-20 or SAE 5W-10

The above recommendations are for engines in good condition. If your engine

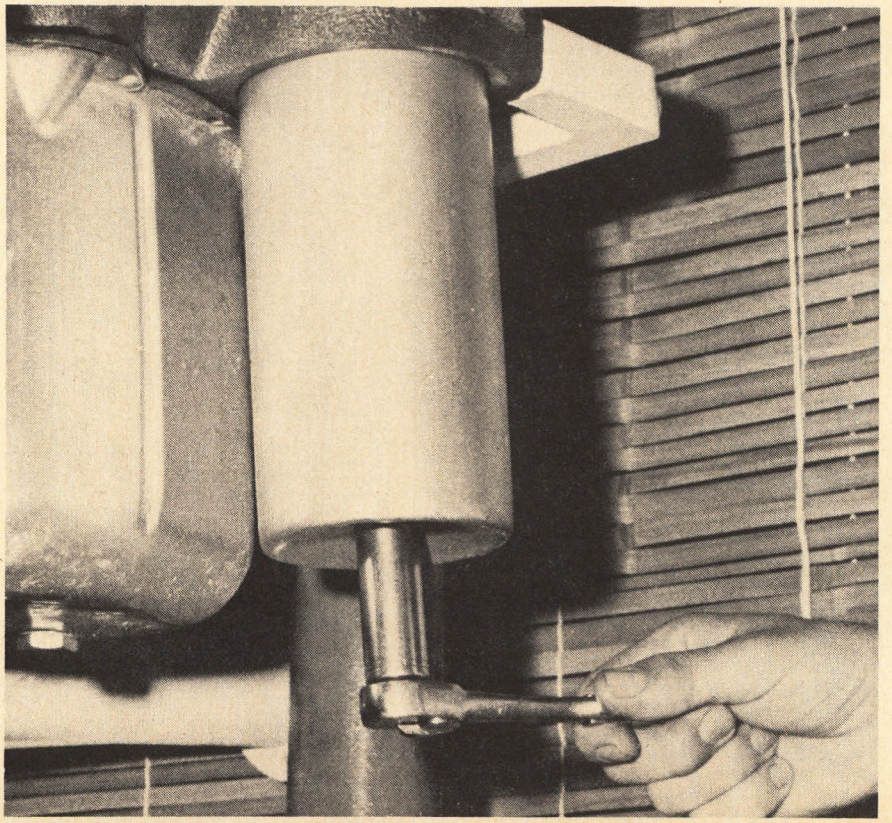


1. Determining Oil Properties

2. Lubricating Filter Gasket



3. Spin-On Filter Adapter



4. Cinching Down Filter Can

is clanking, or using oil, it's a good idea to go to a higher viscosity, such as 40 or 50 wt. The heavier oil will result in less oil consumption, and may keep the engine together longer because it fills in the excessive space between parts caused by wear.

CHANGING OIL

While motor oil does not lose its "oiliness," it does wear out as its additives are used up in performing their function. That is one particular disadvantage of multi-viscosity oil, which is really more additive than oil. It must be changed regularly. The oil in the crankcase, while performing its many functions to protect the engine from harmful effects of contamination, becomes more and more loaded with these waste products, not all of which can be trapped by a filter. Oil filters help if properly maintained, but they don't prevent varnish deposits, sludge, or corrosive wear caused by liquid contaminants which will pass through the filter. There is only one sure way to remove contaminated oil from your engine, and that is by changing the oil on a regular basis before the additives are depleted. Adding makeup oil to a crankcase of dirty oil is no substitute for draining and refilling. Today, as always, 3 qts. of dirty oil and 2 qts. of clean oil make 5 qts. of dirty oil.

Automobile manufacturers vary slightly on their recommendations of oil change intervals. And today's new car standards are not retroactive to older model cars. Therefore, engine oil and filter should be changed every 90 days or 3000 miles, whichever occurs first. These figures apply to almost all driving conditions and are well within the manufacturer's recommendations and those of the American Petroleum Institute.

It's advisable to drain the crankcase only after the engine has reached normal operating temperature. The benefit of draining is, to a large extent, lost if the crankcase is drained when the engine is cold, as some of the suspended contaminants will cling to the sides of the engine block and oil pan and will not drain out readily with cold, slow-moving oil. Allow sufficient time for the oil to drain out and replace the plug carefully, starting the threads by hand so as not to strip the oil pan. Oil pan plugs should be torqued 30 to 40 ft.-lbs. After changing the oil and the filter, do not accelerate the engine beyond idle until the oil light goes out or the pressure gauge reads above 20 lbs. of pressure.

Flushing the crankcase with oils or solvent solutions other than a good grade SAE 10W oil is not recommended. If flushing is necessary due to contamination, fill the crankcase with 3 qts. of SAE 10W oil (4 qts. with filter) and idle the engine at 1000 rpm until the oil is hot; then drain the pan and filter immediately after stopping the engine. Install a new filter and the correct grade and quantity of engine oil.

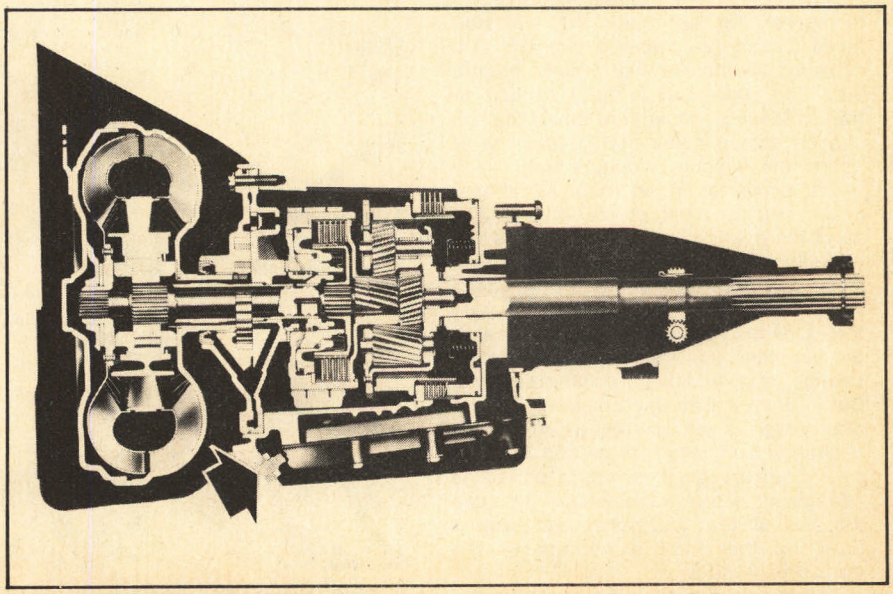
The engine oil dipstick is marked *"full"* and *"add oil."* These notations are marked with broad lines and arrows so that you will know exactly how much oil is in the crankcase and how much you should add if necessary. Never let the oil level go below the lower mark and never overfill the crankcase. Before adding oil, wait until the oil level reading is just below the "add 1 qt." line. Also, if the car has been driven, you will avoid a false reading if you allow a few minutes for the oil to drain back to the crankcase before checking the oil level.

OIL FILTERS

There are two types of oil filter systems: full-flow and bypass. In the full-flow type, the oil filter is in the system between the oil pump and the engine so that all the oil has to go through the filter before it reaches the engine. When flow through the filter is restricted by dirt (which means the filter is doing its job), a valve in the filter (or in the engine block) opens up and allows the oil to go around the filter. Most people don't realize that the valve also opens when the oil is cold, because cold oil is too thick to pass through the filter element. The valve can also open during high-speed operation, because so much oil is being pumped that the filter element can't accept it all.

In the bypass filter system, the filter is on a separate line. Oil goes from the pump to the filter, and then dumps back into the pan. A bypass filter can be removed, and the line plugged, without affecting the operation of the oiling system. On many older cars, the bypass filter was an accessory added by the dealer if the owner wanted it. Bypass filters are supposedly obsolete, inefficient, and unnecessary. But when you consider how much of the time a full-flow filter is

5. Pulling Breather Cap



6. Automatic Trans Drain Plug

1. Oil types and viscosity properties are found printed on the back of the can. Weight and classification (10W-40, SD, SE) shows this grade of oil will protect the engine's moving parts in a wide variety of driving conditions. Check factory recommendations for your particular car and the climatic changes it will be subjected to before you replace your oil.

2. The neoprene gasket must be lubricated with engine oil before filter element is installed. Element is torqued to a recommended 25 ft.-lbs.

3. Up until 1968, Chevrolets used a steel canister with filter element inside, which was messy to change. Now your Chevy dealer and auto parts store have these kits adapting Chevys to the modern, spin-on oil filters.

4. Filter can should be cleaned in solvent, filled with new oil and the cartridge replaced before it's tightened. Care must be taken not to under- or overtorque. Too much will warp can or break gasket; too little won't allow can to seal properly.

5. The steel mesh in the breather cap must be checked and cleaned before you add new oil. Plugged breather can have a bad effect on crankcase ventilation.

6. Most manufacturers of automatic transmissions advise that the ATF (automatic transmission fluid) be changed every 24 months or 24,000 miles, whichever arrives first. Most drain plugs are located in the pan.

actually bypassing the oil, then the old bypass filter doesn't look so bad. Any filtration is better than none; your engine needs the protection.

Most late model cars use a "can"-type filter that screws onto a special mounting bracket attached to the engine. To change it, you merely unscrew it and throw it away. A complete new element is then screwed on in its place. Before attaching this type of element, wipe gasket area of base clean, coat the neoprene gasket with engine oil, and screw the filter can onto its base until the gasket is firmly against the sealing surface. From that point, turn the filter can an additional ½-turn.

Most filter makers consider that anything beyond a ¾-turn will result in the need to use blasting powder to get the filter off when it comes time to change it. But Chevrolet has experienced some leaks when following the ¾-turn rule. They recommend 25 ft.-lbs., which is equivalent to between 1 and 1⅔ turns.

Some throwaway filters have fluted ends that fit a special wrench. Others have a hex so you can use ordinary socket wrenches. Some filters have only a smooth can, so you must use one of those wrenches that looks like a kitchen jar opener and is sold in all the auto supply stores.

Earlier filters are contained in a steel can which also mounts on the engine in either a top or underneath mounting position. The top-mounted filters have a lid that you can remove by unscrewing a bolt. Then lift the filter element out. On filters mounted under the engine, the whole can and filter element is removed when the bolt is loosened. In either case, the filter element is thrown out, the container can wiped clean, and a new element replaced.

Remember, the filter holds 1 qt. of oil. Therefore, if you change the filter when you change the oil, you will need to add an extra quart of oil to fill the crankcase.

AUTOMATIC TRANSMISSIONS

Most automobile manufacturers seem to agree that automatic transmission fluids should be changed every 24,000 miles or 24 months, whichever occurs first. The exception is hard service or trailer towing, in which case the oil change should come at 12,000 miles or 12 months, whichever occurs first.

The converter in an automatic transmission holds most of the fluid and it stays there when the transmission is not operating. Draining the pan will only get a few quarts of fluid out of the transmission. If the converter has a drain plug that can be reached from underneath the car, then you can make a complete change of automatic transmission fluid. But in many cases, the converter has no drain plug. So the only thing you can do is change the amount of oil that is in the pan. Even though it is only a partial oil change, it is still a good idea because the new oil that you put in will help to build up the additive content of the transmission fluid.

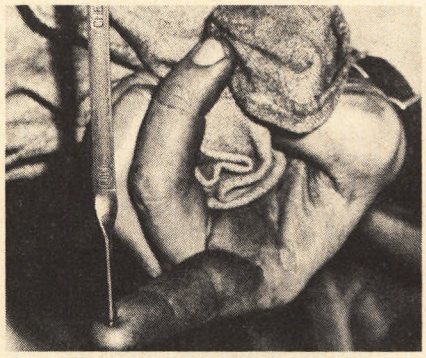
As mentioned earlier, to check the fluid level in an automatic transmission, the engine must be at normal operating temperature. The check must be made with the engine idling and the selector lever in "P" (Park) position. When the fluid is hot, the level should be in the "add 1 pint" mark. *Caution: Do not fill above the "full" mark as this will cause foaming and will result in improper operation.* If it is necessary to check the fluid level when the transmission is cold, fluid level should be at, or slightly below the "add 1 pint" mark. If it's below this mark, add just enough oil to bring it up to the "add 1 pint" mark. This avoids overfilling.

For many years, the only kind of automatic transmission fluid available was Type A, sometimes called Suffix A. In recent years, Ford came out with their own fluid called Type F, which is now available from all fluid manufacturers. Type F is the only fluid that should be used in any Ford product automatic transmission. This includes the older transmissions for which Type A was originally recommended. Some of the early Chrysler, DeSoto, Dodge or Plymouth automatic transmissions were of a different design, actually amounting to a manual transmission that was hydraulically shifted. Most of those old units, including the one called Fluid Drive, were filled with engine oil. Before adding any kind of fluid to any transmission, check the factory specifications to be sure you're adding the right fluid.

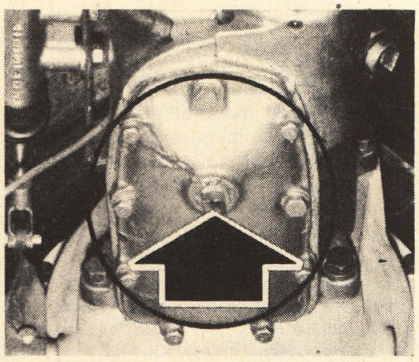
Due to severe engine overheating or heavy-duty towing, the transmission fluid should be checked to determine if the fluid has deteriorated. Deteriorated fluid, if allowed to remain in the transmission, will cause early transmission failure. To check for fluid deterioration, wipe a small amount of fluid off the dipstick with your fingers. If it smells like burnt toast, replace it.

STANDARD TRANSMISSION

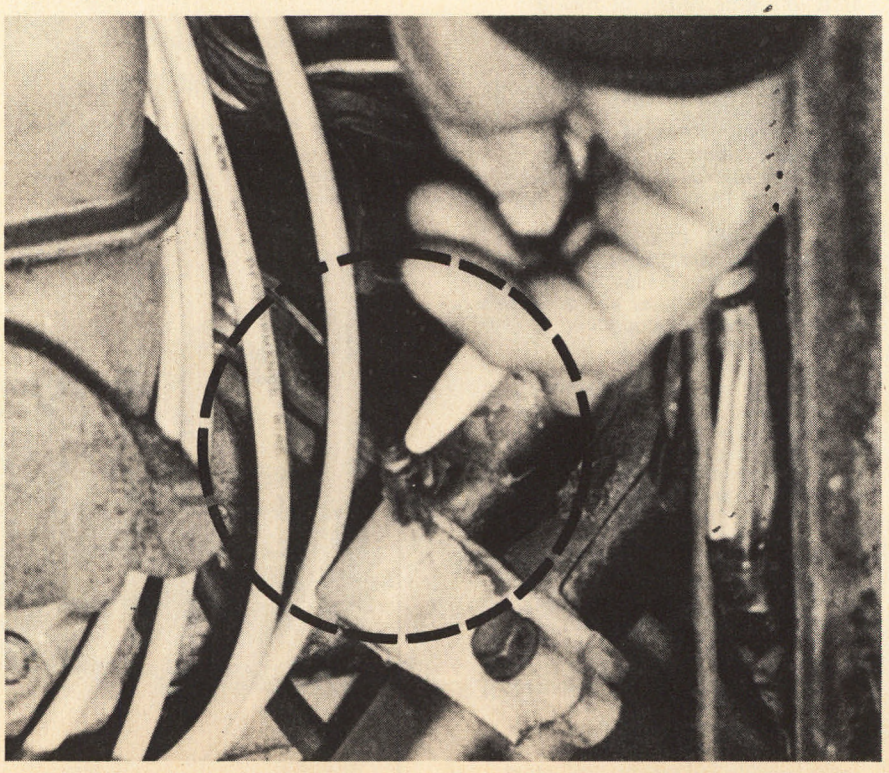
Most auto manufacturers state that regular transmission oil changes are not necessary on late-model cars whose operation is classified as normal service for passenger cars. This is difficult to go along with and it certainly is not true for the older models. No one is absolutely perfect at shifting, and every time there is a clashing of gears—or even the normal wear of transmission parts—there are bound to be metal particles suspend-



1. Checking Trans Dip Stick



2. Manual Trans Drain Plug



3. Shift Linkage Grease Fitting

ed in the oil. And there is no filter in the transmission to catch these metal particles. Therefore, transmission oil on early model cars should be changed every 6 months or 6000 miles. On newer cars with full synchromesh gears, change the oil every 12 months or 12,000 miles. On some late-model cars there is no drain plug; on others a drain plug is provided at the bottom or low on the side of the transmission for this purpose. If no drain plug is provided, a suction pump must be used to remove the oil.

SAE 90 viscosity grade oil is recommended for year-round use; however, SAE 80 may be used when low temperatures are encountered. Good quality multi-purpose lubricants are defined by the number MIL-L-2105B. Except for checking fluid level at engine oil change intervals and draining the oil, there is no maintenance on the transmission other than lubricating the gearshift mechanism. A 30 wt. engine oil is excellent for this purpose, and you should wipe all the pivot points clean before oiling. Some older cars have a grease fitting on the steering column to lubricate the shift levers and linkage.

Many lubricant manufacturers now make multi-viscosity transmission lubes as well as engine oils. In some cases, it is difficult to find single-viscosity transmission lube such as 80 or 90. The 90-140 that most stations carry now seems to work just as well as the old single-viscosity grades.

STANDARD AND LIMITED-SLIP REAR AXLES

On most late-model cars you will not find a drain plug at the rear axle. Late-model cars may go 2 years or 24,000 miles before the fluid should be changed. Older model cars should have their oil changed every 6 months or 6000 miles, whichever occurs first.

Again, the oil level should be checked with the fluid hot, and it should be up to the bottom of the filler plug. If checked cold, it should be ½-in. below the filler plug. Also, SAE 90 viscosity grade oil that meets MIL-L-2105B standards should be used. *Caution: Straight mineral oil gear lubricant should not be used in hypoid rear axles.*

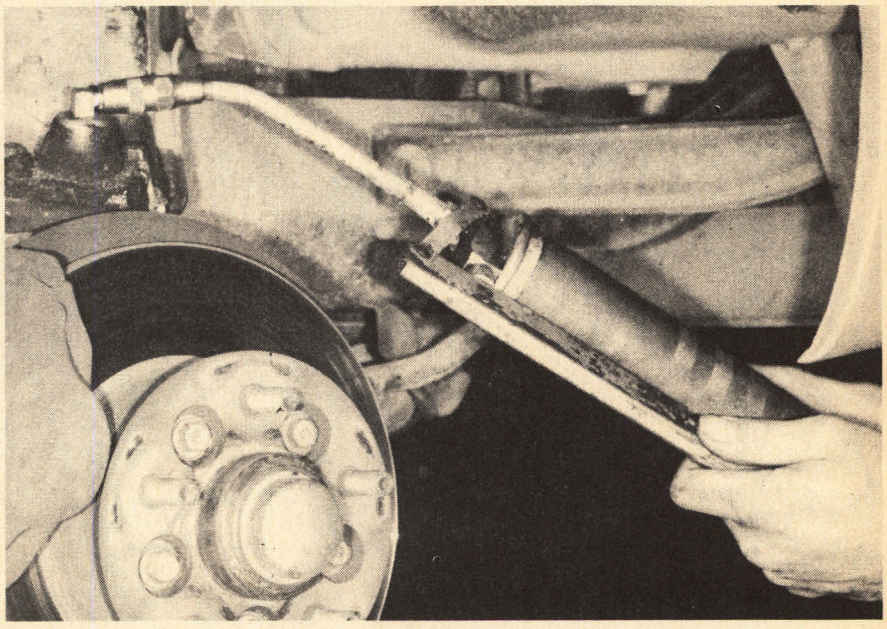
Positive traction rear axles use a special lubricant intended for limited-slip differentials. Some oil companies have a high-quality, multi-purpose gear lubricant that can be used in all types of rear axles; however, if the wrong lubricant is used, no harm will be done except that you will feel a chattering on the turns. If this happens, suction the wrong lubricant out and replace it with the correct anti-slip fluid. Allow about 50 miles of driving for the correct fluid to work its way in between the clutch plates. Turning from right to left will help work it in by exposing plates to the oil.

If the rear axle is submerged in water, such as on a boat launching ramp where water can enter the axle vent, and contamination is suspected or evident, replace the lubricant immediately to avoid early axle failure.

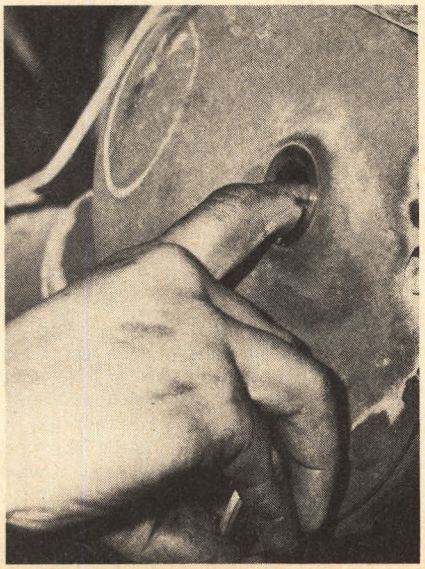
CHASSIS

Between 1961 and 1963, American automobile manufacturers introduced what is called "long-life" front-end ball joints that only require lubrication every 3 years or 36,000 miles, whichever occurs first. These semi-permanently lubricated ball joints should be inspected every 6 months—or whenever the car is serviced—for signs of damage to seals, which can result in loss or contamination of lubricant. The special seals at each joint are the key to this extended lubrication period, and if they become damaged in any way they must be replaced and the joint lubricated.

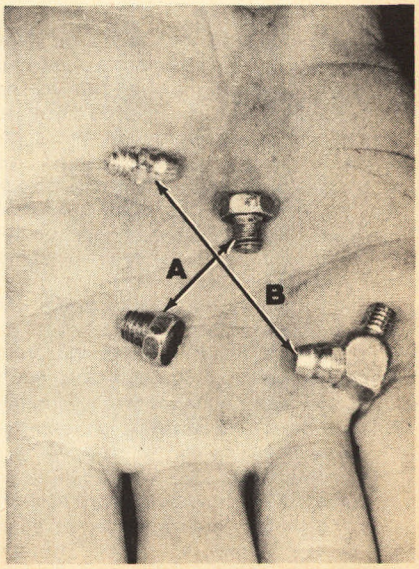
It's easy to tell if your car has the



4. Hand-Operated Grease Gun



5. Determining Rear End Oil Level



6. Threaded Plugs vs. Grease Fittings

1. Fluid level and smell are both important when you eyeball the trans dipstick. Too much or too little fluid can drastically affect the performance of the unit. And so can overheating. If fluid is acrid or extremely pungent, it has been subjected to severe heat and must be changed.

2. Manual transmissions should have their 90-wt. oil replaced every 6 months or 6000 miles. Gear or synchromesh particles, held in suspension by the thick oil, quickly increase unwanted gear and synchromesh wear.

3. The shifting linkage on older cars have "Zerk" fittings which need to be zapped with grease annually.

4. Low-cost, hand-operated grease guns, although not as fast, will do every bit as good a job as the air-operated ones found in gas stations or dealer's repair shops. Many outfits come complete with swivel heads for difficult-to-reach fittings.

5. The oil level in the third member should be checked only after it has achieved running temperature. "Posi"-type units require a special limited-slip differential lubrication to keep the clutches from chattering.

6. Late model cars are equipped with threaded metal plugs (A) instead of grease fittings (B) The plugs are removed at lube intervals and replaced with the Zerk fitting.

long-life ball joints: the car will not have any grease fittings. Instead you'll find a tiny threaded metal plug. The procedure for lubricating these new type ball joints is to remove the plug and screw in a special grease gun fitting. Stop filling when lubricant begins to flow from bleed area at base or at top of seal, or if seal begins to "balloon." Remove the grease fitting and reinstall the plug.

The only types of lubricant that should be used in these semi-permanently lubricated joints are moly-disulfide greases. They are long lasting and highly waterproof.

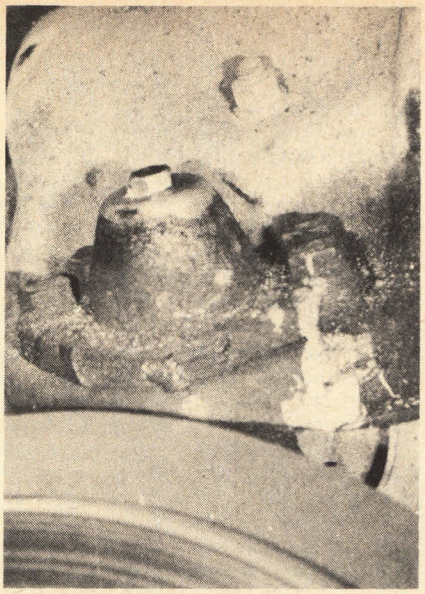
Cars without the long-life ball joints should be lubricated every 60 days or 4000 miles. These joints have what are called Zerk fittings installed at each lubrication point, and if you expect to have a trouble-free front end and one that is safe, you must lubricate these joints regularly. The reason is that these Zerk fittings, even though they have a ball-check valve that doesn't let grease leak out, do let in a small amount of dirt and water. Also a certain amount of dirt and moisture works its way in at the joint. To get rid of this dirty grease, it's necessary to flush it out with new grease periodically before it does any damage. All Zerk fittings must be wiped clean before injecting any new lubricant.

While it's possible that you may want to lubricate your own car with a hand-operated grease gun, it's easier and faster in a service station with a high-pressure grease gun. Also, a service station or car dealer will have a complete lubrication chart (number of fittings, location, types of lubricant and refill quantities) on every car so that you can be sure of a thorough job. There are exceptions to this if you have replaced any factory parts that did not have a lubrication fitting with one that does. An example might be universal joints or idler arm, in which case you must make the attendant aware of the change, so that he does not miss properly lubricating it.

Other chassis pivot points such as rubber shock absorber bushings, spring leaf bushings and leaf liners or pads, and anti-sway bars do not require lubrication. They are made to run dry and if they wear out, they should be replaced. However, after many years and miles of use they sometimes get squeaky; then, and only then, should they be lubricated with a special rubber lubricant spray. Be sure to mention this to your dealer too, as they sometimes make it a point to spray only older cars.

Clutch, brake and parking brake linkages should also be lubricated about every 6 months. Wipe all the pivot points clean and lube with 30 weight engine oil. Lubricate pivot points inside car sparingly so as not to cause dripping which will stain upholstery.

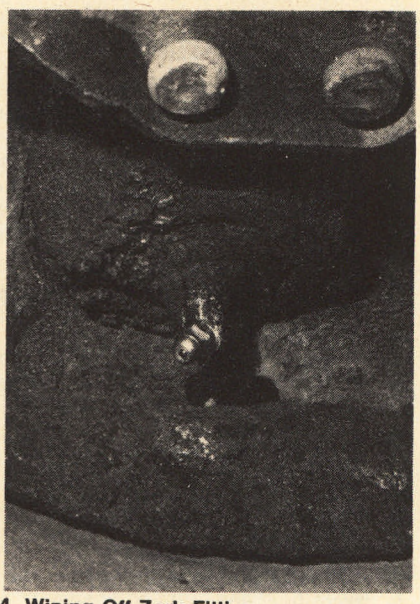
On some older cars (especially Ford products '32-'48) it is necessary to lubricate the clutch throwout bearing shaft, and a Zerk fitting is provided for this purpose. Use only a small amount of lubricant, as excessive grease may work its way onto the clutch and cause it to slip when engaged.



1. Locating Metal Plugs

2. Removing Plugs

3. Tightening the Zerk Fitting



4. Wiping Off Zerk Fitting

UNIVERSAL JOINTS

Most cars, except some of the late models, will have lubrication fittings at the driveshaft universal joints. They should be lubricated every 4 months or 6000 miles, but sparingly and very carefully so as not to pump out the seals. On cars with torque tube drive there is only one fitting, and that is where the driveshaft meets the transmission output shaft at the ball joint. This joint must also be lubricated carefully so as not to damage the rear transmission oil seal.

On some late-model cars without lubrication fittings on the universal joints, the manufacturers say that lubrication is not necessary for the life of the joint and that only periodic inspection is necessary to check for leaking seals, in which case either the seal may be replaced or the complete universal joint.

Because auto manufacturers vary so widely on universal joint lubrication, it's best to consult your owner's manual to see if lubrication is advisable for your make, year and model. If there is no universal joint grease fitting and lubrication is advisable, it should be done every 2 years or 24,000 miles. To lubricate this type of joint it is necessary to remove the driveshaft and disassemble the U-joints as if you were going to renew the bearings. (That operation is described in the chapter on driveshafts.)

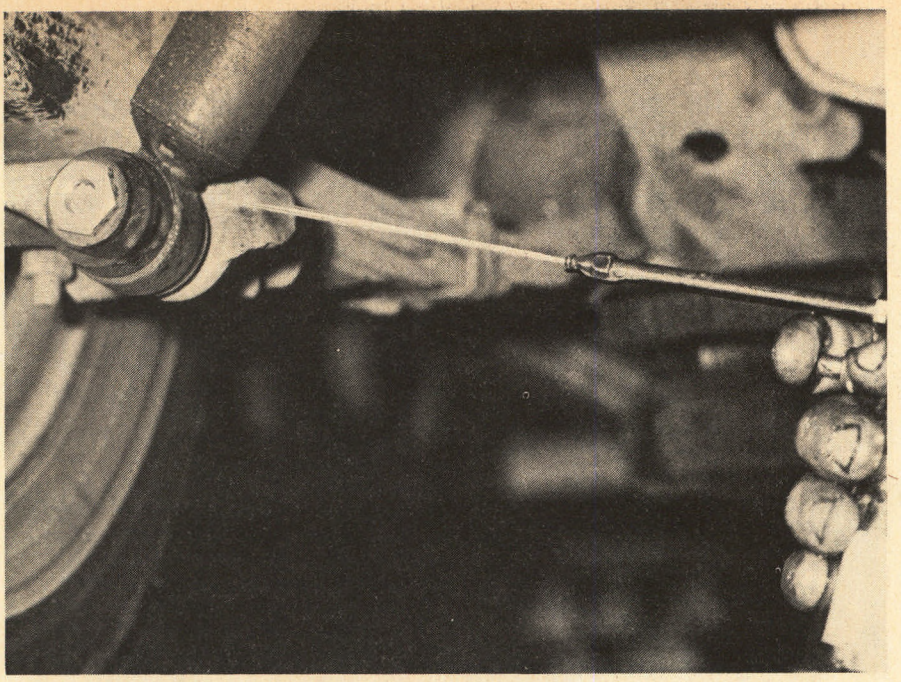
STEERING GEAR

The lubrication installed in the steering gear at time of assembly is a high-quality product, and regular or seasonal changes are not normally required.

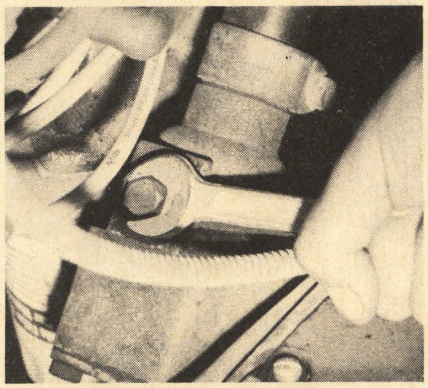
Steering gear oil level should be checked at every engine oil change interval; its normal level is up to the filler plug. Some steering boxes use grease instead of oil. Your owner's manual or local lubrication expert will tell you which should be used.

POWER STEERING

Check the power steering reservoir level at every engine oil change. The



5. Lubing Rubber-Mounted Pivot Points



6. Loosening Screw on Steering Box

1. The threaded metal plugs are found installed on semi-permanently lubricated ball joints. Clean away all dirt and grease before removing.

2. A small socket wrench works best for plug removal. Some shops will replace the plugs after greasing the car; you're ahead of the game if you leave the Zerk fitting in.

3. Screw the Zerk fitting in by hand as far as it will go, then tighten snugly with an open end wrench. Using the angle fitting on top of the ball joint makes greasing a bit easier. The straight fitting works fine on the bottom of the ball joint.

4. All Zerk fittings must be wiped free of old grease or road scum build-up before fresh grease is added. The accumulation will contaminate the fresh grease if this isn't done.

5. Rubber-mounted pivot points on shocks, springs, torsion bars, etc., are lubricated with a silicone-based rubber lube applied with a squirt can, but only if they are squeaking. Otherwise they should be left dry so they won't slip and wear out.

6. The oil or grease level in the steering gear—normally up to the filler plug—must be checked at the same time you change oil and filter.

reservoir will either have a dipstick for measurement, a *full* mark on the housing or a notation on the cap to *fill* to ¼-in. *below* top.

Most power steering units use automatic transmission fluid, but special power steering fluid is available, and the units seem to work a little bit better on it. Both special steering fluid and the auto trans fluid will mix compatibly, so there is no necessity for emptying the system when adding fluid. Do not overfill any power steering unit. Overfilling can cause pressure to build up that would blow the seals in the pump.

WHEEL BEARINGS

Front wheel bearings are one of the most important lubrication points on a car and yet one of the most neglected. It is highly imperative that they be cleaned, repacked and the seals inspected every 12 months or 12,000 miles. This includes all cars, both old and late models regardless of make.

To lubricate the front wheel bearings, it's necessary to remove the wheel and hub assembly.

The condition of ball and roller type bearings that have been in service cannot be judged until they are thoroughly cleaned. There is always enough dirt present to affect the "feel" of the bearing and give the impression that they are rough.

Bearings with seals or shields on both ends should not be washed in solvent since there is no way to replenish the grease supply. This type is merely wiped clean and checked for a rough or noisy "feeling."

Unsealed bearings should be washed thoroughly in clean solvent which has not been used for other parts. Slosh the bearings up and down rapidly in the solvent to flush out all dirt and metal particles. It may be necessary to soak hardened dirt and lubricant from bearings; however, do not let them touch the bottom of the pan and pick up any dirt that may have settled there.

After washing, blow out the bearings with clean dry air, directing the air stream squarely into the open side. Hold the inner race and turn the outer race slowly by hand. *Never spin the bearings with air pressure.* It's not only hard on the bearing, but dangerous. That bearing will spin at several thousand rpm, enough to make it disintegrate like a fragmentation grenade, and you know what damage they can do.

Most dealers with service stations have a pressure packing tool that forces the lubricant throughout the bearing. This is the best way; however, it may be done by hand by carefully pushing the grease down in between the balls or rollers. It takes time to do this, and you must work the grease in from all open sides.

Rear wheel bearings get their lubrication by "splash" from the rear axle gears, although some very old cars have a lubrication fitting at the ends of the axle housing. Check this out. Also, they only require one quick shot of lubricant so as not to damage the seals or force lubricant into the braking surface areas.

AIR CLEANERS

There are four main types of carburetor air cleaners in use today: the dry replaceable paper element, the oil-wetted wire mesh air cleaner, oil-wetted polyurethane, and the oil bath type.

The dry replaceable paper type should be cleaned every 6000 miles and replaced every 12,000 miles or 12 months. To clean this type of filter, drop it repeatedly and squarely on a clean, flat surface until all loose dust has been removed. Turn element over and repeat process. Air blast cleaning is okay if done very carefully. Now visually inspect the element for any breaks or holes in the fiber and replace if any dust leaks are found. Before installing element, wipe all dust from interior of air cleaner and install element by turning 180° from removal position. When element and cover are in place, tighten wing nut securely by hand to insure a good seal.

Oil-wetted wire mesh cleaners must be cleaned every 4000 miles. This type is washed in clean solvent by sloshing up and down and then setting aside to drain dry. Oil the element liberally with 30 wt. engine oil, allow excess to drain off, and reinstall your element.

The polyurethane type filter is washed in clean solvent and squeezed dry. Soak in 30 wt. engine oil and replace element. This type of element may be cleaned every 6000 miles in most areas.

Oil bath air cleaners are serviced by emptying the oil reservoir and washing the entire unit in clean solvent every 10,000 miles. The reservoir is then refilled with 30 wt. engine oil to the level indicated on the unit. Some oil baths also have a wire mesh filter which is serviced as outlined for this particular type.

Never dunk an entire air cleaner in solvent. You may think you are going to get it really clean, but all you will do is get solvent inside the air chamber, and it will take you about 2 weeks of rich run-

Lubrication

ning on your car before all the stuff evaporates.

Oil filler caps with mesh breathers should be washed every 4000 miles with solvent. Slosh the cap up and down in the solvent rapidly and tap squarely on a flat surface until all dirt is removed. Allow cap to drain until dry and lubricate with 30 wt. engine oil.

On late-model emission-controlled cars, the breather mesh that used to be in the oil filler cap is now in the air cleaner at the end of a hose running from the sealed filler cap. The reason for the breather mesh inside the air cleaner is not to protect the engine, but to keep oil fumes off the air cleaner element. Clean the breather mesh in solvent, but leave it dry when you replace it.

GENERATORS AND ALTERNATORS

Most generators have oil cups at one or both ends of the housing. These cups should get 2 or 3 drops of 30 wt. oil every 2000 miles or at engine oil change interval.

Alternators are equipped with sealed bearings and lubrication is not possible. If a bearing goes bad (usually from water, so cover vent holes when washing or steam cleaning your engine), it must be replaced. No other maintenance is necessary except wiping dust from vents.

DISTRIBUTOR

Most distributors, except on late-model cars, have an oil cup outside the housing. This should be filled every 2000 miles or at engine oil change interval with 30 wt. oil. Many distributors have a felt wick underneath the rotor. A few drops of oil on the wick will keep it moist so that the breaker cam will move freely on the shaft. However, the wick does not lubricate the advance weights. They should be checked whenever the points are going to be replaced.

WATER PUMP

Almost all water pumps have sealed bearings which never need service for the life of the pump. When the bearing goes bad the pump is replaced. However, preventive maintenance means adding a can of Rust Inhibitor and Water Pump Lubricant to your radiator every 6 months, unless you are running antifreeze. In that case, the antifreeze is all you need. Adding rust inhibitor to the antifreeze might prolong the life of the water pump, but in our experience it lowers the boiling point of the coolant enough to cause boiling over and coolant loss.

Some older cars have a grease fitting on the water pump, and this type should be lubricated every 2000 miles or at engine oil change with special water pump grease. It's waterproof.

EXHAUST MANIFOLD VALVE

The exhaust manifold valve should be lubricated at every engine oil change to keep it operating properly. Any sticking of this valve will impair engine efficiency. Lubricate both sides of the shaft with a mixture of graphite and kerosene, or you can purchase special exhaust manifold valve lubricant at a parts store.

ACCELERATOR LINKAGE

All the pivot points in the accelerator linkage should be lubricated at the 10,000-mile mark when the engine tune-up is performed. It's not difficult to understand that smooth operation of the accelerator linkage is important to safety and control of your car. Use 30 wt. engine oil on all pivots and grease on all sliding arms. Some car makers suggest keeping linkage dry, so it won't pick up dirt and wear faster.

SPEEDOMETER CABLE

To service a noisy speedometer cable, disconnect the cable at the speedometer head and remove the shaft. Clean the shaft thoroughly and then lubricate. Insert the shaft back in the cable, being careful not to let it touch the ground and pick up any dirt. Wipe the excess lubricant from the end of the cable and reconnect to the speedometer head.

CONTROLS AND SEATS

Once a year do a little spring lubing

1. Determining Fluid Level

2. Greasing Wheel Bearing

3. Lubricating Door Lock

inside the car. Dash control knobs that you push and pull should be wiped clean (remove any rust spots with crocus cloth) and lightly lube with grease. Push the knob in and out to work in the lubricant. Also lubricate the open cable ends where they attach to the heater, the air conditioner, windshield wiper, fresh air intakes, etc. And don't forget the seat tracks. It's always annoying and diffucult to try to adjust a seat that won't slide smoothly. Lubricating power seats is especially important.

BODY LUBRICATION

Don't forget there are literally hundreds of body parts that need regular lubrication too, and they should be serviced every 6 months to keep your car in top condition.

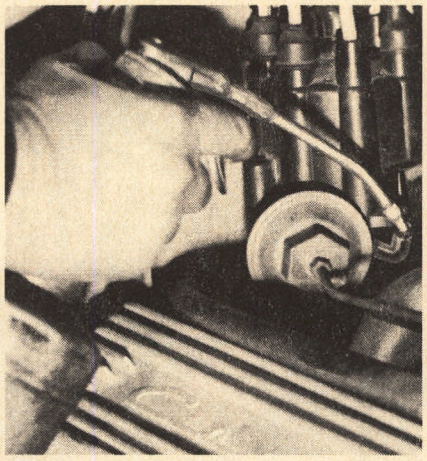
All rotating parts and hinge pins are to be lubricated with 30 wt. engine oil. All sliding and rubbing contact parts are lubed with grease. The only exceptions to this are the door and tailgate striker plates and bolts, and the ends of the sunshade rods which require non-staining stick-type lubricant—and the door key locks which use powdered graphite.

Accumulated dirt, dust and old lubricant should always be wiped off before applying new lubrication. Then operate the mechanism to work it in, wiping off any excess. All rubber moldings should be lubed with a special rubber lubricant to keep them from weather cracking and prolong their life. Rubber lubricant soaks into rubber and soon disappears. We have been experimenting with silicone (either spray or grease) and find that it does an excellent job of protecting rubber parts from deterioration.

Start at the front and work your way back. Lubricate the hood latch, release cable and safety mechanism and the hood hinges. The doors are next—striker plates, door locks, striker rotor, hinges and hold-open mechanism and/or torque rods, the latching mechanism and key lock. If you have a station wagon or pickup, don't forget the tailgate hinges, lock and support rods. And way out back, put a little lubrication on the gas cap cover door hinges. If you have a convertible, you'll want to do the folding top mechanism, but apply it sparingly (have a rag handy) so as not to get any lubricant on top of upholstery. Oil frequently seeps out onto the paint a few days after lubing door hinges and other body parts, so use just as little oil as possible, unless you want to be a traveling advertisement for 3-in-1.

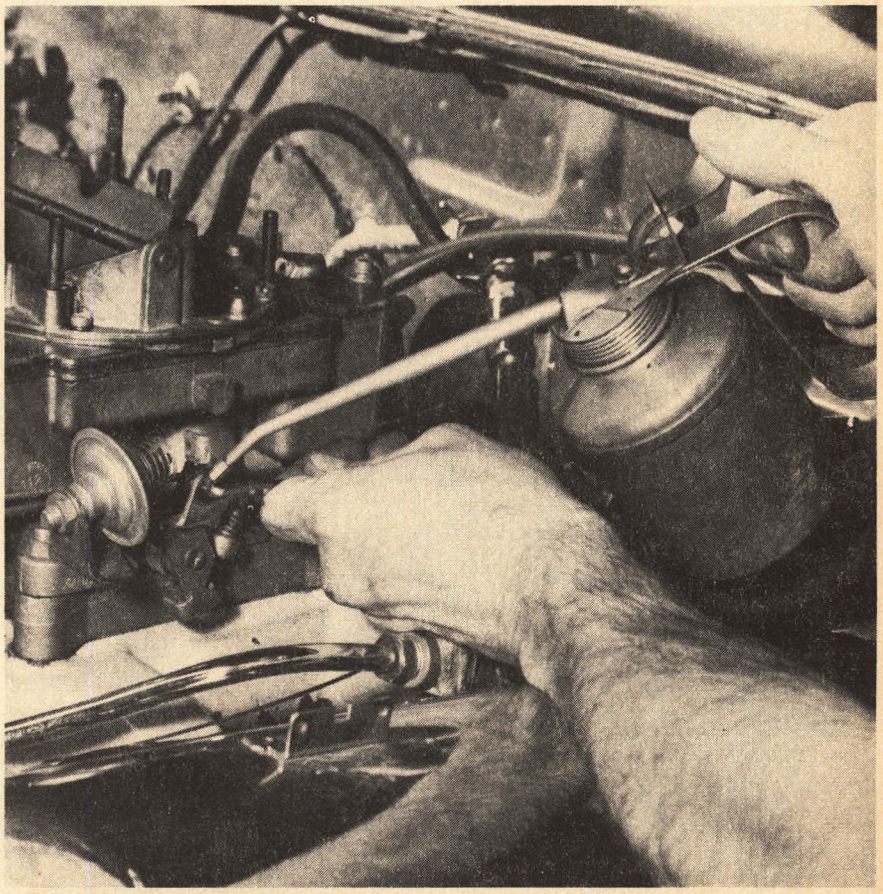
We'll leave the window regulators up to you. Normally, they will probably never need care unless you have an older car, or trouble develops inside the door panel. But if it's difficult to turn the window crank, remove the upholstery panel and determine the cause. It may just need aligning and lubrication. By servicing it now, before it breaks entirely, you'll save some money.

To remind you of your regular lubrication and maintenance program, the accompanying chart will tell you at a glance the items that need service on a "mileage" and "time interval" basis. As previously mentioned, some of the items will need adjustment according to your driving habits and geographical location. Stick to it and your car will always be in top condition and serve you reliably.



4. Oiling Distributor

5. Greasing Hood Latch



6. Lubricating Throttle Linkage

1. Like the steering gear, the fluid level in the power steering reservoir must be looked at every 3 months or 3000 miles. Don't overfill reservoir.

2. Repacking the wheel bearings can be done by man or machine. Some use a bearing packing tool to force the grease between the rollers or balls. The hand method means you must put a large dab of grease in the palm of your cupped hand and stroke the bearing over the material, forcing it in between the balls or rollers.

3. An occasional blast of spray lube in your door and trunk locks will save you time and trouble, especially in cold climates. The new silicone or graphited lubes are excellent.

4. From the generator we'll move to the distributor. Most have an oil cup on the outside of the housing which needs a drop or two of 30-wt.

5. The moving parts attached to the car's body require periodic servicing. Work your way back from the front, catching the hood latch, release cable, safety catch, etc., then on to the door latches, hinges, striker plates, trunk lid catch, key lock and trunk hinges.

6. If it moves, don't salute it, lube it! All pivot points in the throttle linkage require the oil treatment every 10,000 miles.

Tuning Your Engine

Ever since somebody coined the word "tune-up" it has been used and abused so much that nobody really knows what it means anymore. Probably the main reason is that nobody knew what the guy meant when he conceived the term in the first place. If we ever meet him, we will certainly ask.

Because a tune-up varies so much, depending upon what garage or what mechanic is doing the work, we can only tell you what we feel a tune-up should include. We have known garages that included a check of the brake fluid and a windshield cleaning in their regular tune-up procedure. There's certainly nothing wrong with that, but what we will deal with here are just the bare necessities in what we consider a basic tune-up.

AIR CLEANER

Much of a tune-up involves using your naked eye to look for parts that are out of adjustment, worn out, or just plain dirty. For instance, the first thing that is usually done in any tune-up is to remove the air cleaner. We do this for a couple reasons. The most obvious is to get the cleaner out of the way so we can work on the engine. The other is to examine the filters that are inside it to see if they are in need of replacement.

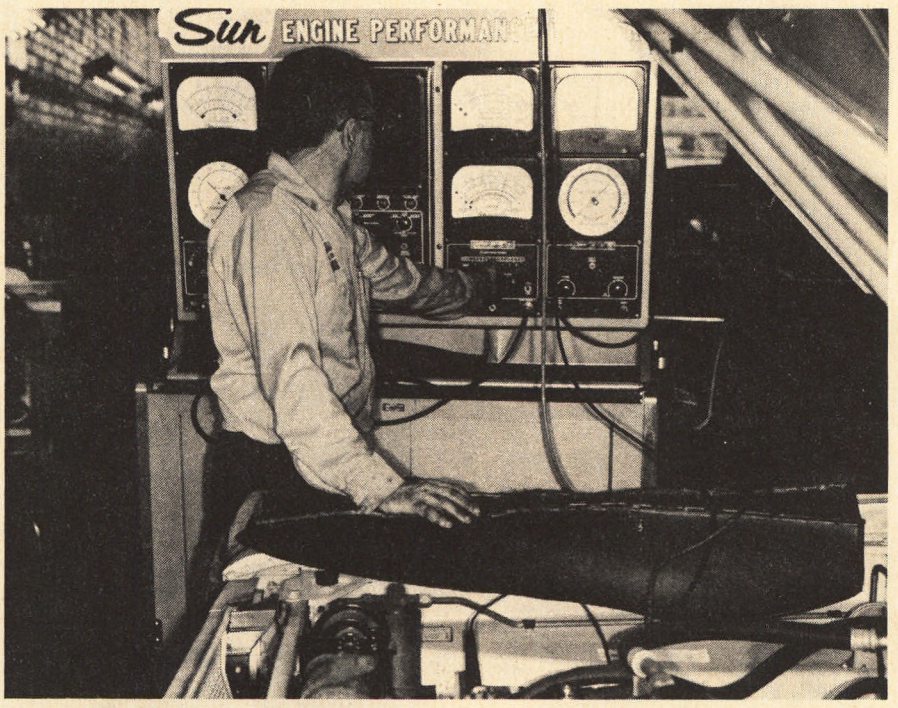
If your car has the type of filter that traps dirt because it is moistened with oil, then all you have to do is wash it out in solvent, put some clean oil on it, and it's ready to go back on the car. Incidentally, if you should be washing any of the old-fashioned air cleaners that have a large silencing chamber, do not submerge them in a bucket of solvent, because the solvent will run inside the silencing chamber where you can't pour it out. It will take about two weeks to evaporate out of there, and all during that time your car will be running rich because of the solvent fumes.

Many cars today use the dry type of air cleaner element made out of folded paper. You don't need any fancy testing rigs to determine if it is good. Just hold the element up to a naked light bulb and you can see if it's clean or not. On late model cars, there is another filter inside the air cleaner can that stops oil fumes coming from the hose that connects to one of the rocker covers. That filter should be washed out and reinstalled.

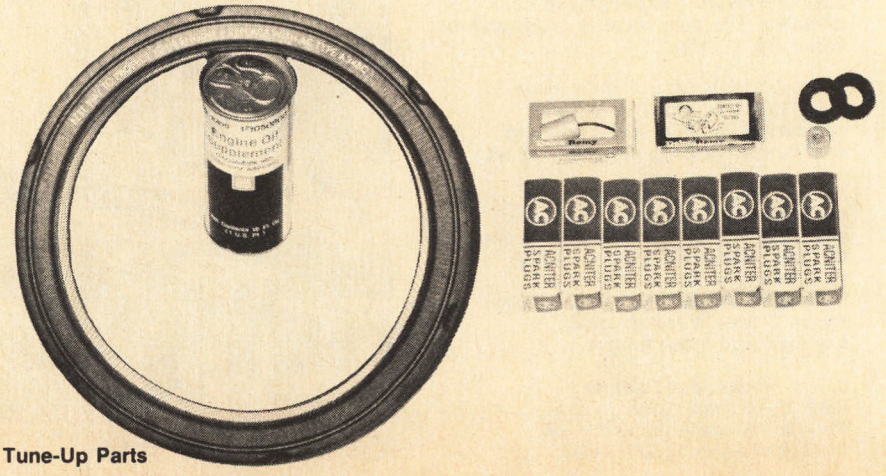
GUM AND VARNISH SOLVENT

Removing the air cleaner exposes the top of the carburetor. So this is an excellent time, before you touch anything else on the engine, to feed some tune-up solvent through the carburetor with the engine running at a fast idle. This is a step that is seldom done in commercial garages because it smokes up the neighborhood and it takes a lot of time. However, it is probably the most important part of the whole tune-up. It must be done before the tune-up is started, not afterwards. The tune-up solvent does a good job of loosening up carbon accumulations in the cylinders. The carbon starts flying around and one of the first places it lands is on the spark plug. Sometimes the loosened carbon will foul the plugs so badly that they can't be cleaned and reused. So the only way to do it is when you know you are going to change the old plugs anyway.

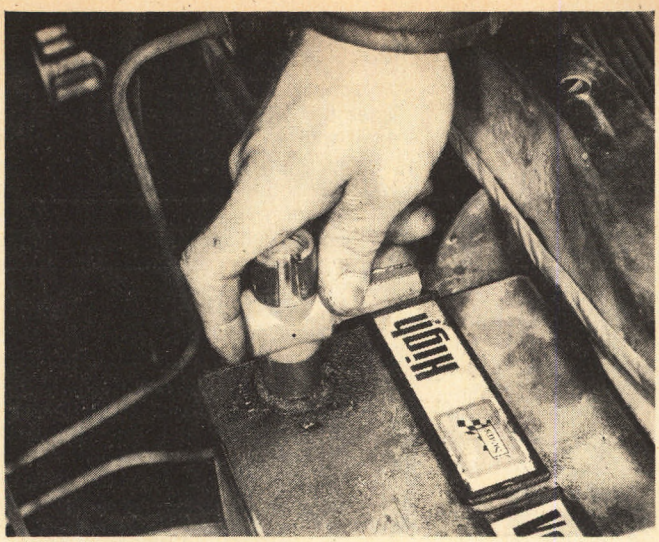
When feeding the tune-up solvent through the carburetor the basic idea is to feed it as fast as you can without killing the engine. It amounts to a delicate balance between one hand holding the throttle and the other tipping the can. When you get down to the last part of the solvent, let it all run in so that the engine is flooded and dies. Then let the car sit a while so that the solvent will have a chance to work on the combustion chamber deposits. The final step is the blowout. Drive the car slowly and accelerate from zero to 30 at wide-open throttle a few times. Continue until all the smoke is gone and you can see out the rear window once again.



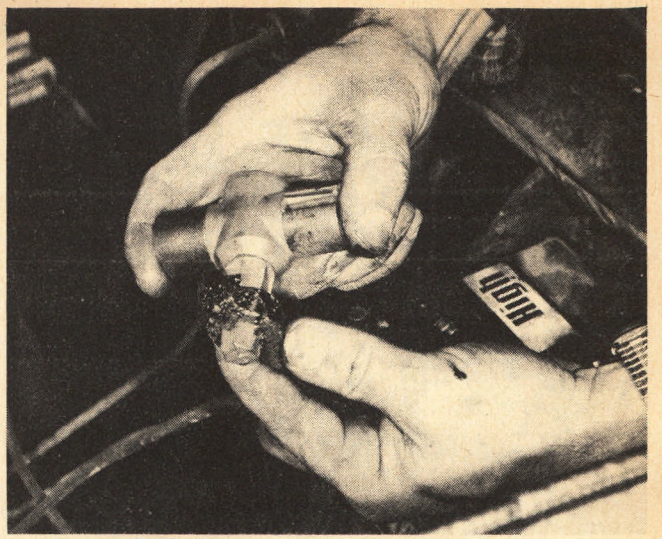
1. Professional Tune-Up Equipment



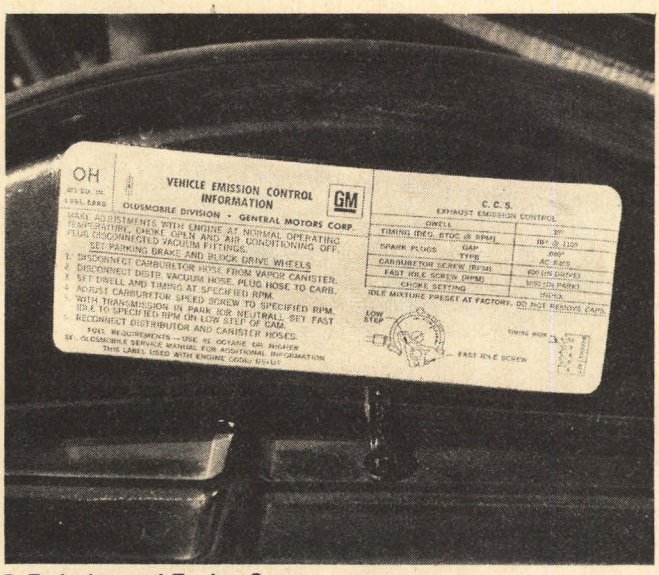
2. Tune-Up Parts



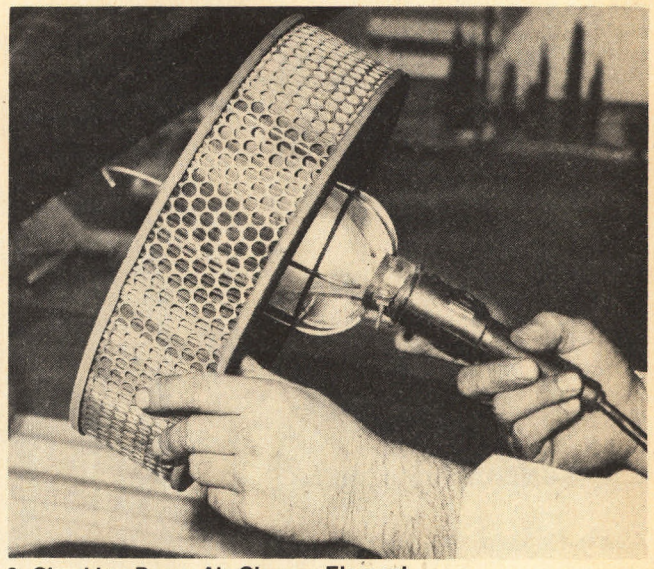
3. Cleaning Battery Posts



4. Cleaning Cable Ends



5. Emission and Tuning Specs



6. Checking Paper Air Cleaner Element

1. Much exotic new professional tuning equipment has been developed over recent years, but do-it-at-homer can still do the job himself, though it will take longer than for a pro.

2. Parts used in most basic tune-ups include air and fuel filters, spark plugs, point set and condenser.

3. Cleaning battery posts is a snap with this dual-purpose tool by Snap-on. Leading edge on heavy gauge snap ring does the trick nicely.

4. With its six metal blades embedded in plastic, Snap-on battery tool has wide edge on older wire brush terminal cleaner; this one really does the job quickly and cleanly.

5. On the newer cars with the smog systems, special tuning information is on a label in engine compartment.

6. A dirty air cleaner element can cut your gas mileage considerably. You can check the condition of one by shining a droplight through the back. If light won't go through, then you should replace the element.

7. If you have access to an air hose you can blow (from the inside) some of the loose dirt out of an air cleaner and recheck with droplight.

CRANKING VOLTAGE

Cranking voltage at the battery terminal of the ignition coil should also be checked before you proceed any further with the tune-up. If while making the cranking voltage test you use a tachometer or your good ear to tell if the engine is being cranked at a normally fast cranking speed, then you have checked the battery, the generator, the starter, the ignition switch and the wiring in just a few seconds.

If that doesn't sound right to you, let's analyze it. When the cranking speed of the engine is normal, you know that the starter and the battery are good. If the coil is receiving at least 9 volts, you know that the wiring from the battery through the ignition switch to the coil must be good. How about the generator? Well, if the battery cranks the engine normally and supplies normal voltage to the coil, it must be adequately charged. And if it is charged, it follows that the generator has to be OK.

The cranking voltage test is done with a remote starter button which is connected to a terminal on the starter solenoid so that you can operate the starter directly from the battery. On some cars, you can't reach the solenoid, so the way

7. Cleaning Dry-type Element

to do it is to use an ice pick to connect with the wire that runs from the solenoid to a plug on the firewall. The procedure varies with the make of car. If you have trouble and can't seem to get the starter to work with a remote starter button, the easy way to do it is to just sit in the car and use the normal ignition switch. Position your voltmeter so that you can see it through the windshield during cranking, and the job's done. Remember that the voltmeter goes to the battery terminal of the coil, not to the distributor side. To keep the car from starting so that the engine will crank long enough to get a good reading on the voltmeter, you

should pull the wire out of the center tower of the distributor cap and use a short jumper lead to ground it to the engine. Another way of keeping the engine from starting is to either disconnect or ground the wire to the points. Be very careful you don't ground the wrong wire, or you will burn up the ignition switch, and maybe the car, too.

The battery only puts out a little over 9 volts during cranking because of a phenomenon known as voltage fall-off. Were you ever in an old house where the lights used to dim every time the refrigerator went on? A similar thing happens when the battery is operating the starter. A tremendous amount of current is flowing out of the battery, which causes the battery voltage to drop. We expect a certain amount of voltage fall-off, so long as it's not too much. If the voltage falls off too much, we know that the battery is weak or worn out, or there's a bad cable connection, etc. We check the voltage at the battery terminal of the coil because that is the most important point. If you don't have sufficient voltage there, you don't get any spark.

If you don't get at least 9 volts at the coil during cranking, the first thing to check is the battery. A 12-volt battery should put out approximately 12.6 volts when it's not running anything. If it only puts out an even 12 volts, it is low. If you don't have a voltmeter, you can't very well check cranking voltage, but you can listen to the cranking speed, and that will tell you quite a bit in itself.

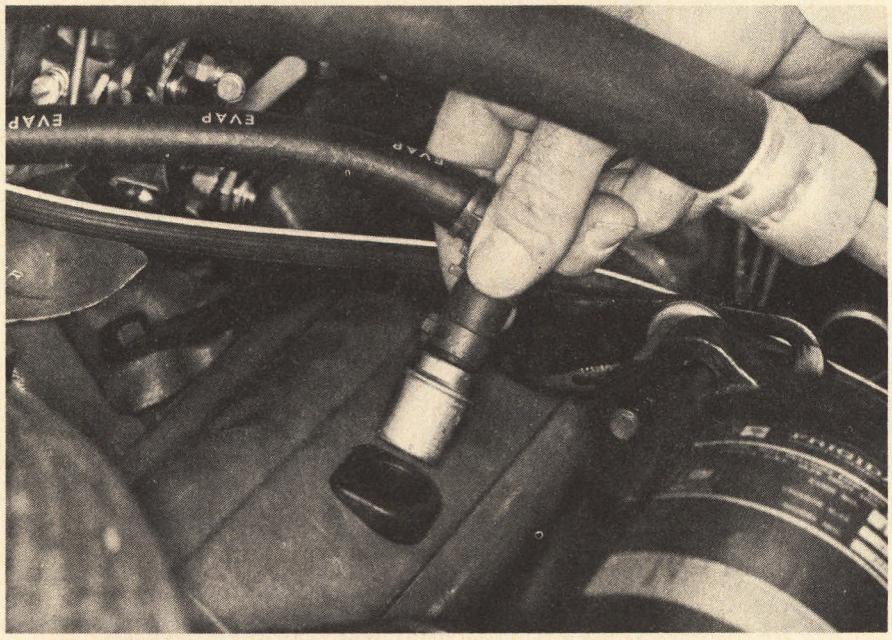
TUNE-UP EQUIPMENT

A tune-up is only necessary once a year or every 12,000 miles. So it's hard to justify purchase of a voltmeter or other tune-up equipment if you are only going to use it once a year. However, with the cost of labor skyrocketing these days, you will find that buying a tune-up in a garage will cost you more than buying all your own tune-up equipment and parts and doing the job yourself.

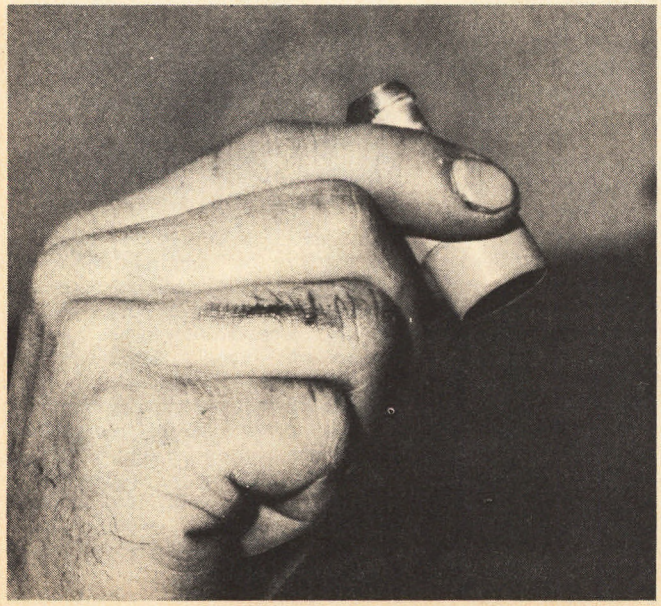
Only a few pieces of equipment are necessary in order to do a tune-up. It would be nice if you had a timing light, a tachometer, a dwell meter, a remote start button, and a compression gauge. The only one that you really need is the timing light. Sure, it is possible to set timing statically, but on a modern engine there is too much chance for error, and the recommended way is to use a light while the engine is running. The tachometer you can do without, because you can pay a garage man a couple of dollars to set the idle speed for you. The dwell meter is not necessary if you have a specification book which will tell you what the point gap should be, and you can set that with a feeler gauge. The remote start button, as we have already pointed out, can be eliminated by using the key switch on the instrument panel.

You may feel that it is absolutely necessary to take a compression check, but it isn't. A garage man takes a compression check only because he has to guarantee his work. He knows that tuning of a car with poor compression is not done because the car should first have a ring and valve job. But even the most horrible old clunker will run better if it has the timing set, points gapped correctly, and the spark plugs either cleaned or replaced.

When you do the tune-up yourself, you don't have to guarantee it to anyone. You just want your car to run better and it will not matter what the compression is. Taking a compression check on your own car will, in many cases, just make you feel bad, because you'll find out some disappointing news that you didn't know before. However, if you are buying a car or checking out somebody else's car, then by all means make a compression check because it will tell you the condition of the engine.

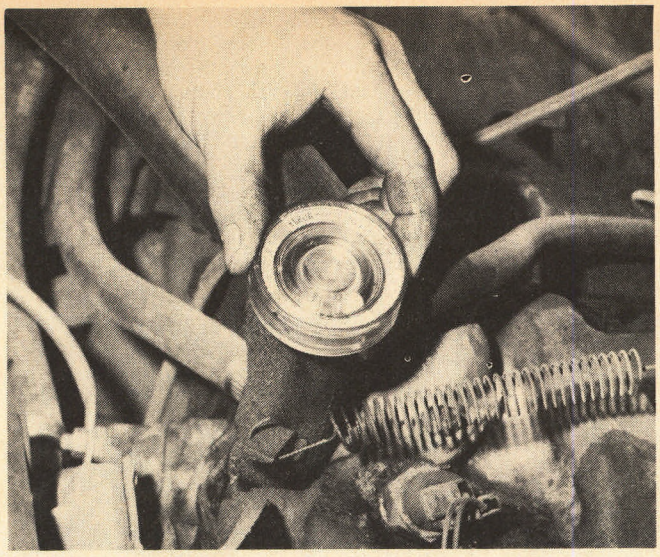


1. Pulling PCV Valve

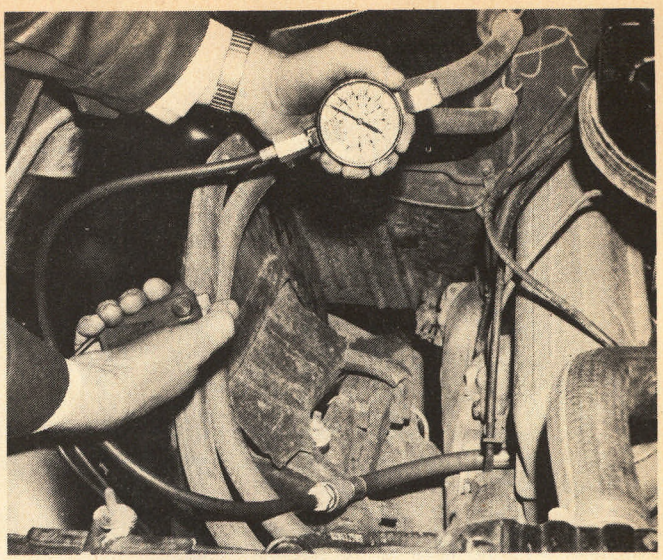


2. Checking PCV Valve

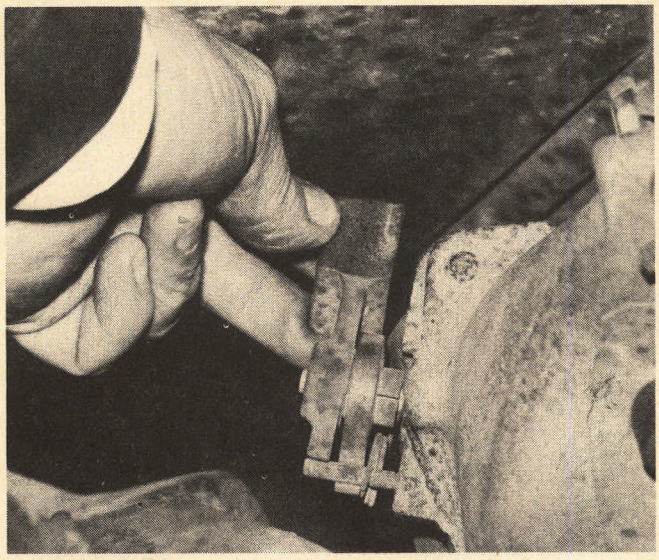
3. Echlin PCV Valve Tester



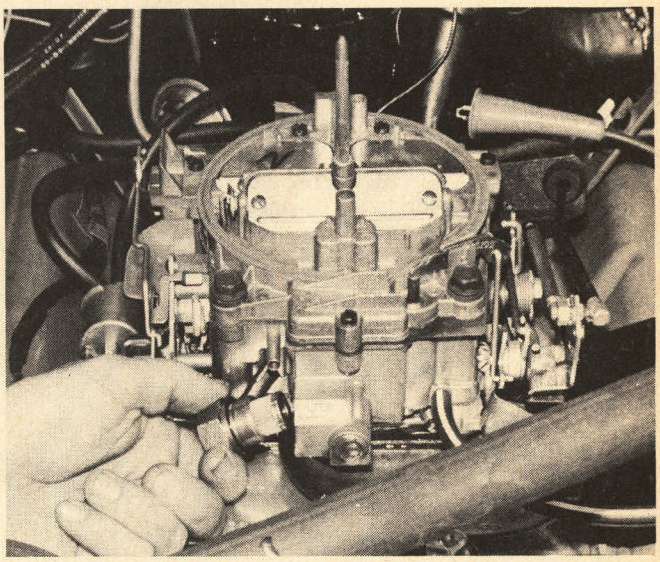
4. Testing Running Engine



5. Making Compression Check



6. Heat Riser Valve



7. Fuel Line Filter

TIMING LIGHT TESTS

If you do have a certain amount of equipment, you should use it to take measurements before you start doing the tune-up so that you will have some basis for making adjustments afterwards. It is entirely possible that the ignition timing or the idle speed is not set to stock specifications. Maybe the idle speed is set a little faster so the engine won't die. Or maybe the timing is retarded a little to take care of cheaper gas, or advanced a little to give more acceleration. If you don't check timing and idle speed before you start fiddling with the distributor, there is no way—after you get the engine running again—that you can get it back to where it was.

Suppose you check an engine that has the ignition timing set 4° advanced from where it is supposed to be. If it runs well, and it doesn't ping, you'd better leave it there because the last guy who set it probably knew what he was doing. Any time you touch the points you automatically change the ignition timing. So if you dive right in to replace them without checking the timing first, you may find that you are experimenting for three weeks afterwards trying to get the timing set to a position that will give the performance you had before you changed the points.

With a timing light, you can also check the vacuum and centrifugal advance curves in the distributor very easily. With everything hooked up normally, all you have to do is run the engine up slowly to about 2000 rpm and watch the timing marks move on the front pulley as you shine the timing light on them. As you open the throttle to run the speed up, the vacuum advance will change the position of the marks, and you can see what's happening right on the front pulley. Pull the vacuum advance line off the distributor and then you can check the centrifugal advance. Of course, you are not accurately measuring the advance when you are doing this, but at least you can get an indication that both vacuum and centrifugal advance are working to some degree.

There are timing lights on the market that have an adjustable electronic delay. With them you can actually measure the amount of advance you are getting on the front pulley, because turning the little knob on the light will bring the marks back in line with each other. It's a slick unit but it's very expensive and not too

1. The PCV valves in your rocker covers or carburetor need to be removed and checked once or twice each year for clogging.

2. By shaking the smog valve, you can hear if the inner element is free. If it rattles, OK; if it doesn't, it's clogged and should be replaced with a new one.

3. Smog valve checkers like these are available inexpensively at most auto parts houses.

4. Holding the checker on the oil filler tube while the engine is running tells you whether system is working or not.

5. Before doing a tune-up, it may be a good idea to make a compression check. It will tell you if there are any major engine problems such as worn rings or valves.

6. It's very important to check for free operation of your heat riser in the exhaust manifold. If it isn't free, spray it with some solvent or choke cleaner.

7. There's usually a fuel filter in the gas line or carburetor that should be replaced periodically.

practical for home use. Your best bet is to check it as we have suggested and if you see the marks jump around, or if it appears that you're not getting enough advance, pull the distributor out and take it down to a garage so that they can set it on the distributor machine.

TUNE-UP PROCEDURE

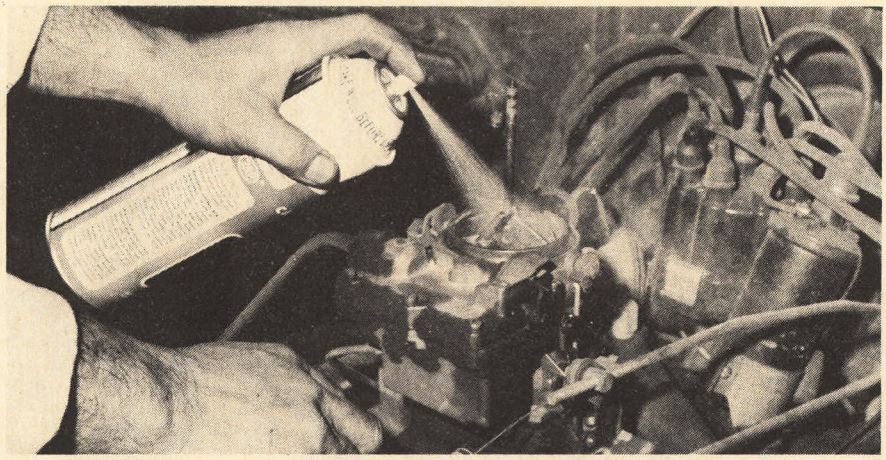
Now we're ready to start the actual tune-up, so we shut the engine off, pull the smog valve and drop it in a bucket of carburetor cleaner. Remove the plugs and take a look at each one, keeping them arranged on the fender or on a bench so that you can remember from which cylinder each one originally came.

Reading spark plugs is not too difficult after you have looked at a few. If they're as black as a coal bin, they are fouled. A kind of dull white to light brown on the plug porcelain is fine. This depends a lot on the year of the car. Late-model cars run so lean that their spark plugs will be just about pure white almost any time you look at them. Modern combustion chambers can run the plugs that white because the plug position in the cylinder is such that the incoming fuel keeps it from burning up. Unless you have a problem with plug fouling, you should use the same heat range plug that came in the engine or its equivalent in another manufacturer's line.

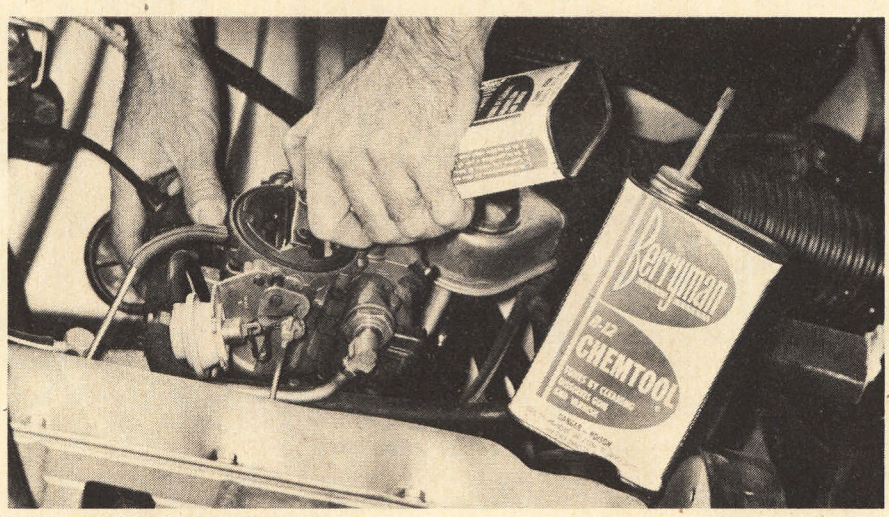
We might mention here about the "rebuilt" spark plugs that you see in grocery stores, drug stores and just about every place except where they sell auto parts. Most of those plugs say "rebuilt" on the package. We don't know what their definition of rebuilt is, but we do know that the rebuilding we have observed consisted only of sandblasting the plugs to clean them. The sandblaster that they use is extremely powerful, much more so than you would find in any service station or auto repair shop. We have used the rebuilt plugs and found in our own experience that they foul much quicker than new or normally sandblasted plugs.

One reason that the rebuilt plugs have prospered is the difficulty of getting anybody to clean spark plugs these days. Most service stations and garages have a plug cleaner somewhere off in the corner that is either broken or hasn't been used for 15 years. There is nothing wrong with cleaning plugs in a normal sandblast cleaner. If they will come clean, the center electrode should be filed to a sharp edge, the gap reset, and they can then be used over again. If the porcelains will not come clean because of splash fouling or other deposits that won't come off, the plugs should be thrown away.

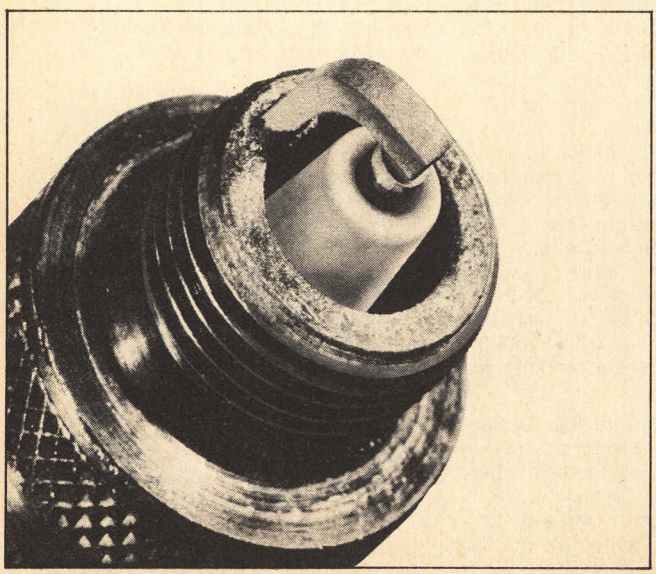
With the plugs out, you should now make a compression check if you're going to do it at all. Then it's time to remove the old points and install new



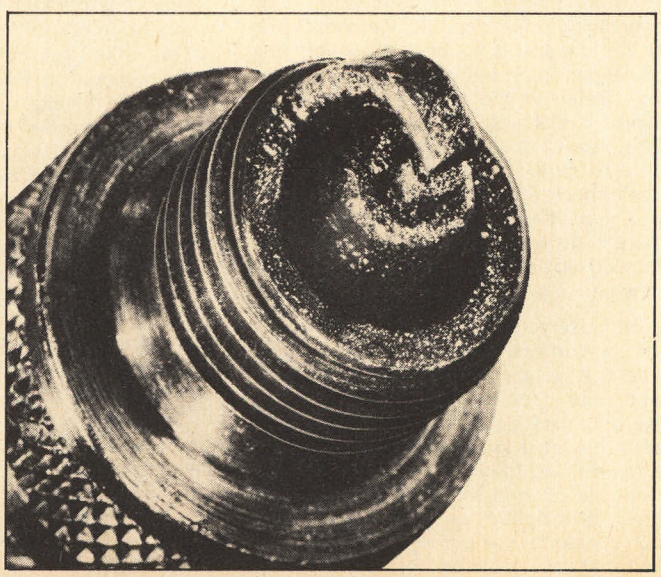
1. Freeing Choke



2. Blowing Out Carbon Deposits



3. Normal Plug



4. Oil-Fouled Plugs

ones. We recommend that you put the points in without removing the distributor from the car. You may have to crawl over the fender and lean on top of the sharp points of the engine in a very uncomfortable position, but installing points in the car will get you into a lot less trouble than pulling the distributor and then trying to get the thing properly timed when you put it back in. In a commercial garage it's a different proposition. They want to check the vacuum and centrifugal advance curves, so they may pull the distributor and test-run it on their machine.

You can tell a lot about the vacuum and centrifugal advance difficulties you may be having just by looking at the distributor parts. If you have a Delco distributor with the weights up on top where they are easily seen, check to see if the weights move freely back and forth and that the springs are not rusty or broken. You can check the vacuum advance just by sucking on the end of it and watching to see if the breaker plate moves back and forth. If it doesn't, there's a hole somewhere and you'd better get a new vacuum advance unit.

If you haven't put points in a distributor before, move very slowly when removing the old points. You want to get the new ones back in exactly the same position with all the screws in the same place and all the leads positioned exactly where they were before. There's a lot of movement that goes on underneath the distributor cap. If everything isn't in the right place, things can get all tangled up, and then it's no spark.

New points are usually lined up fairly well, and there are thousands of mechanics all over the country who don't even look at them before they put them in. But it's a good idea to check the points' alignment because they will last a lot longer if you do. The idea is to have the point faces meet squarely so that in the case of conventional points, the only contact is exactly in the center. If you have the points with the hole in the middle, then the contact is a full circle rather than a single point. Point alignment

1. If you get a lot of black smoke from your tailpipe in the morning, maybe your choke is sticking. Spray lubricant for freeing chokes is available in spray or squirt cans.

2. Pouring a little Chemtool into the carburetor while the engine is running helps to clean out the motor by dissolving carbon and deposits.

3. Light tan or gray-colored ash deposits and some electrode wear are typical of a normal plug. If the porcelain is extremely white, the engine may be running too lean.

4. If the deposits are black and heavy, the trouble is probably that of excessive oil in the cylinders. However, it could also be caused by flooding of the carburetor.

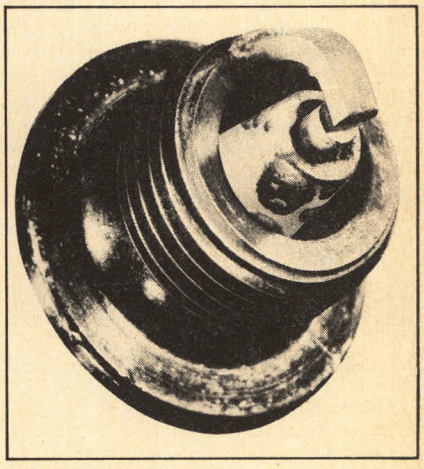
5. Here's the best advertisement for blowing out an engine before you tune it up. That way, the splash fouling will occur on the old plugs.

6. You will see a broken insulator like this every once in a while. It is caused by severe detonation, or it could be caused by pressure on the center electrode when gapping plug.

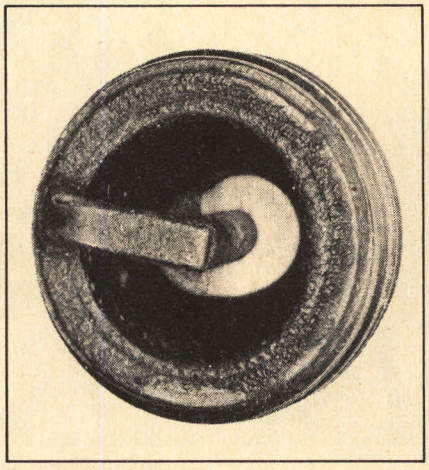
7. These dry, fluffy black deposits may be caused by a rich mixture, which may in turn be caused by a clogged air cleaner or sticky choke. If only one plug is fouled, suspect the electrical circuit to that plug, the plug itself, or that cylinder.

8. Plugs do wear out. If there is a lot of wear on the electrodes and the insulator looks pitted, it's time to replace the plug.

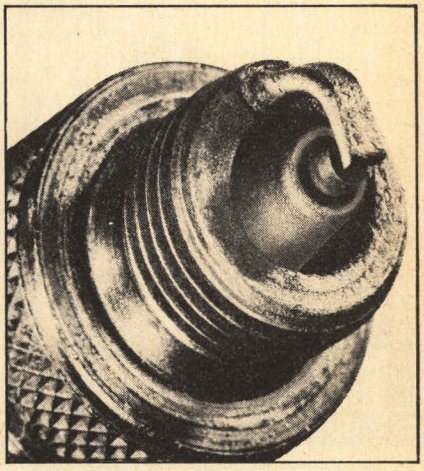
9. Flaky, white or yellow deposit is caused by scavenger additives in the gasoline. These deposits will easily come off in a plug cleaner.



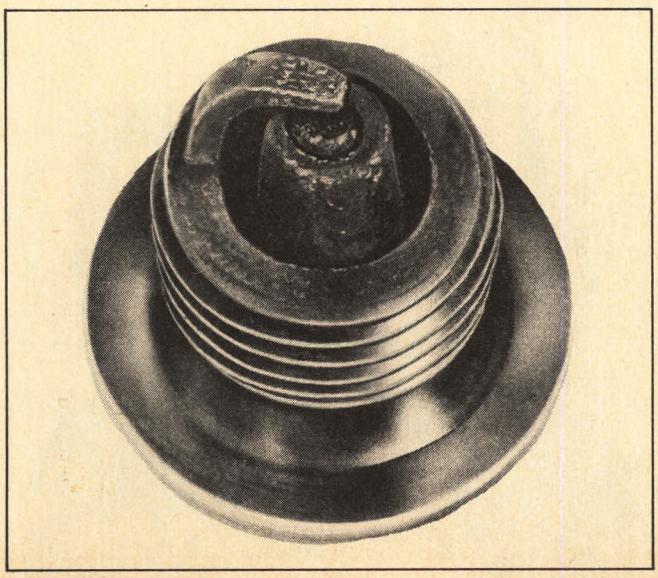
5. Splash Fouling



6. Chipped Insulator



7. Carbon-Fouled Plug



8. Worn-Out Plug

9. Scavenger Deposits

can be checked by looking through the points parallel to their surfaces with a white card held behind them. You can easily see if they are twisted at all. To line them up, bend only the stationary point until the contact faces meet squarely.

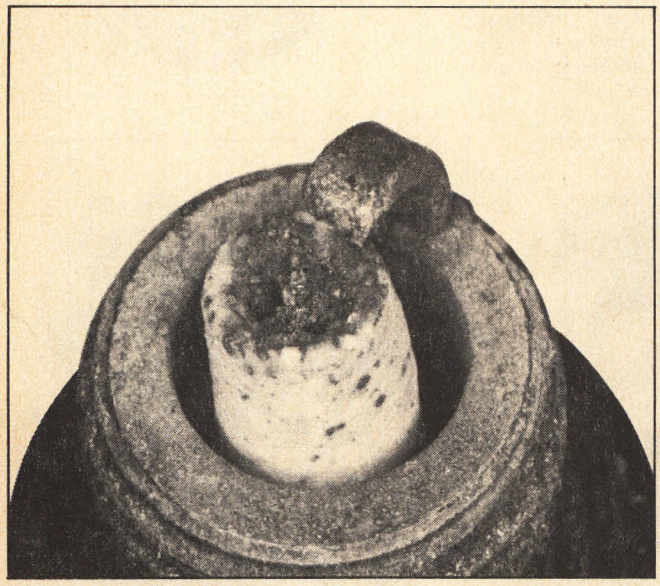
The design of the points will determine whether you do point alignment before the points are put in the distributor or afterwards. On a General Motors V-8, the point assembly is made in one piece so you can do the alignment while you're holding the points in your hand. Some other cars have the points in two pieces with the pivot post mounted on the distributor breaker plate. To align those points you have to have them mounted on the breaker plate in their normal position before attempting to bend the stationary point. You can use ordinary pliers to bend the stationary point, but you might slip and ruin something. A special tool with a hook end is much easier to use.

What you do with the points after they are installed will depend upon your make of car. In a Delco distributor with an Allen head set screw you don't do anything because the point gap will be set after the engine is running. Most other cars require that you use a feeler gauge to set the actual point gap in thousandths of an inch. When you check the gap, be sure that the rubbing block of the points is at the high spot on one of the cam lobes. If you feel like checking things out, measure the point gap on several cam lobes. You'll find that it varies a couple of thousandths. Nothing's perfect these days.

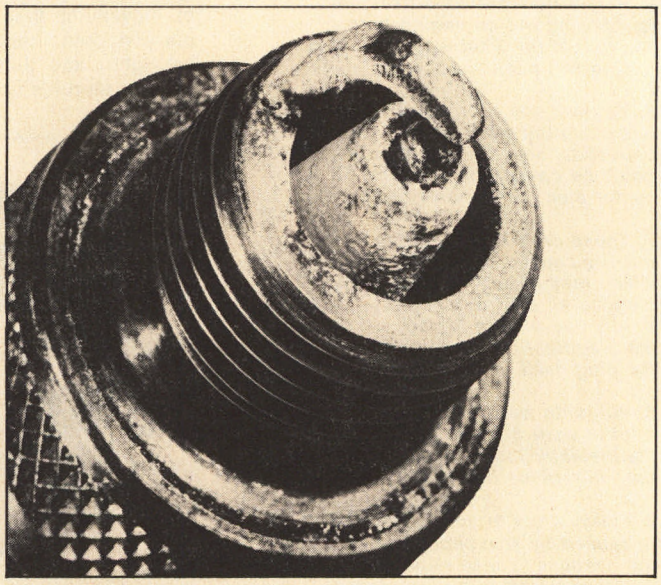
To get the cam lobe exactly under the point rubbing block, you can turn the engine over by pulling on the fan belt. You have the plugs out so it should turn easily. Another way is to "bump" the engine with a remote starter button. The easiest and most accurate way is to loosen the distributor hold-down bolt and turn the body of the distributor either way until you get what you want. After the gap is set, move the distributor body back where it was, so that the engine will start easily.

After installing the points, check the gap on the new plugs. Put a drop of oil on the threads of each plug and then thread it home. If the spark plug wires are all mixed up and you can't figure out which ones go on which plugs, the only way to check it out is by firing order. You can usually find at least one plug wire that you know is on the right plug. Trace that wire back to the cap and then follow the firing order around the cap in the direction that the rotor revolves. This will tell you to which spark plug each wire should go. On most distributor caps, No. 1 is marked so that you have a starting point for your firing order.

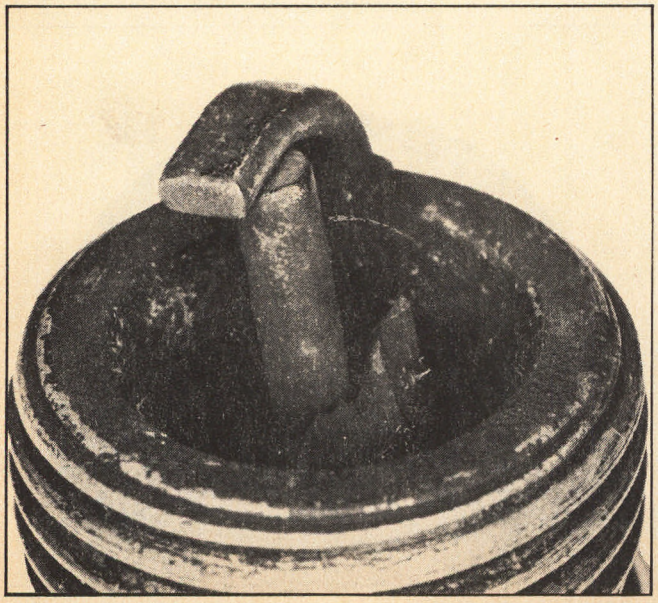
With the plugs in and the wires on, the engine is almost all put together but you're not ready to start it up yet. A good tune-up involves more than just points and plugs. Somewhere in the exhaust manifold you may find a small flapper valve. It's called the heat riser valve and it's responsible for giving good warmup when you first start your car.



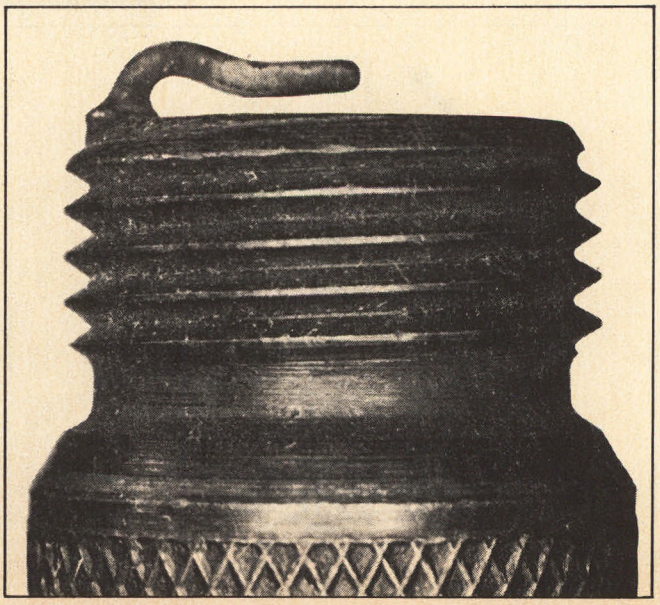
1. Pre-ignition Damage



2. Burned Electrodes



3. Mechanical Damage



4. Bent Side Electrode

The heat riser valve has a spring to hold it in the closed position. It is forced open by exhaust gas pressure when the engine is running at high rpm. The valve should move easily when you touch it and the spring should return it to the closed position when you let go.

What the heat riser valve does is force the exhaust gases through a passageway underneath the carburetor before they can go out through the exhaust system to the muffler. Some cars (mostly Fords) do not have a heat riser valve. They get heat to the manifold by circulating radiator water through a passageway under the carburetor. Late-model cars using temperature controlled air cleaners do not have the valves either; but they do have a flapper valve in the air cleaner snout that gives the engine hot air off the exhaust manifold or cool air from under the hood, depending on the temperature. A quick check for the flapper valve is to move it with your finger to see if it's free. If you want to check it out thoroughly, you can watch it move as the engine warms up.

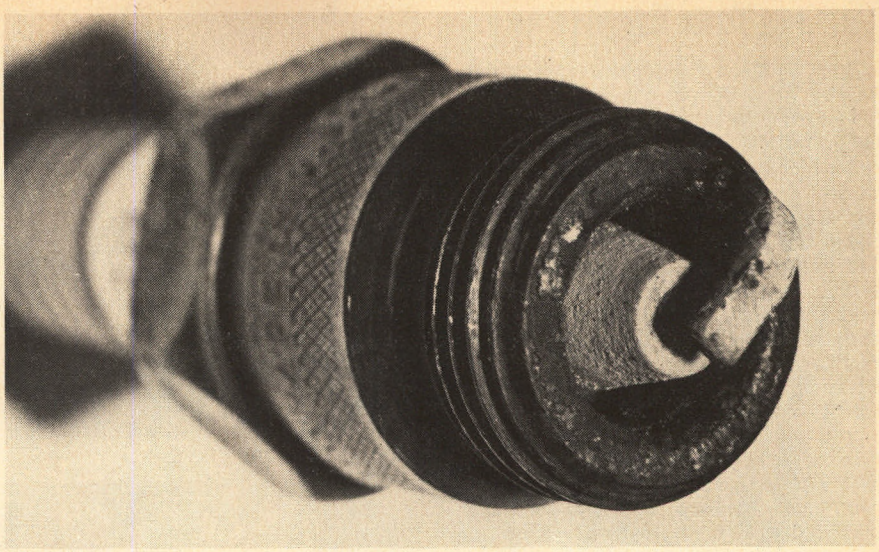
Cleaning battery terminals is also part of the basic tune-up. You should remove them from the posts, scrape away any corrosion that you find, grease the terminals to prevent future corrosion, and then make sure they are good and tight when they go back on.

The fuel filter is another part of basic tune-up. It should definitely be replaced whether it is the inline type or a little insert that goes in the carburetor inlet.

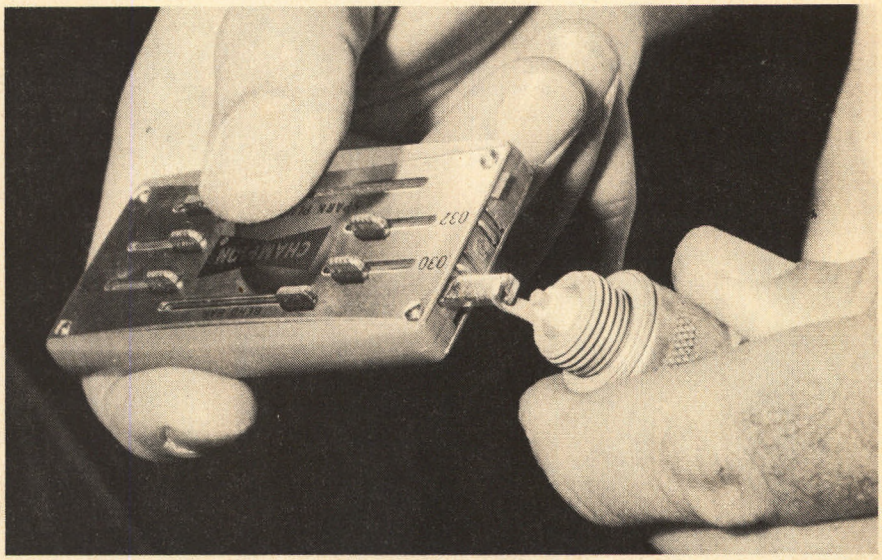
Now that you've done all those chores, it's time to rescue the smog valve out of the carburetor cleaner, wash it out in cleaning solvent and put it back on. Some manufacturers do not want you to clean smog valves. They would rather you replace them. Strictly speaking, they are correct because most smog valves cannot be taken apart to make sure they are clean. But if you can hear the little jiggle-pin rattling in there, you can be pretty sure that the valve is going to operate correctly.

Now's the time to fire up the engine, but check your timing light hookup first. It's much less shocking if you hook it up with the engine dead. On Ford and Chrysler products you will already have set your point gap so you don't have to worry about that. But on a Delco-Remy distributor the point gap is set after the engine is running. If you have a dwell meter, set it to 30° and forget about it. But you don't need a dwell meter with a Delco distributor. Use an Allen wrench or one of the special little wrenches with a cable handle that you can buy in most auto parts stores. Lift the window in the side of the distributor cap and turn the Allen screw clockwise until the engine starts to misfire. Sometimes the engine will just flat die without even giving a hint of misfiring. In either case back off counterclockwise ½-turn and your distributor point dwell will be set perfectly at 30°. Check it with a dwell meter if you want to, but it isn't necessary.

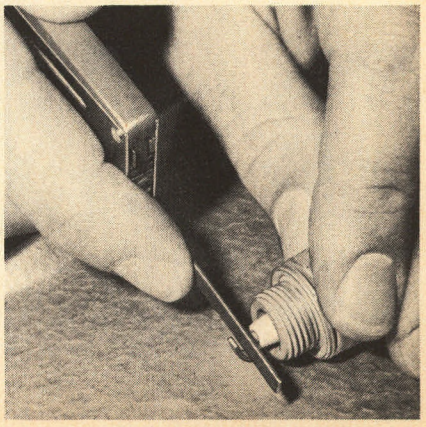
The procedure of backing off ½-turn has been standard for some time, but it has been found that spring tension can cause the screw to move a little later on, if the final turning movement is in a counterclockwise direction. The latest recommendations now call for backing off one turn and then going clockwise ½-turn so that the last movement is



5. Lean, Overheated Plug



6. Bending Side Electrode



7. Filing Center Electrode Flat

1. A plug has to get pretty hot to melt the electrodes like this. It could be caused by lean mixture, an air leak or even crossfire from another spark plug wire.

2. These electrodes have been hot, but not hot enough to melt away. The plug could be the wrong heat range or the trouble could be caused by spark timing or low-octane fuel.

3. Everything's slightly bent out of shape here because of a nut or washer bouncing around in the cylinder. Changing the plug will not solve the problem until the foreign matter is removed from the engine.

4. Some plier-type gapping tools will bend the side electrode like this, which doesn't necessarily ruin the plug, but the same tools also put pressure on the center electrode. This pressure may push the center electrode right out of the plug.

5. White or chalky-grey insulator with tip blistered and electrodes burned is typical of today's plugs. With air conditioning and power options, modern leaned-out engines tend to overheat plugs like this.

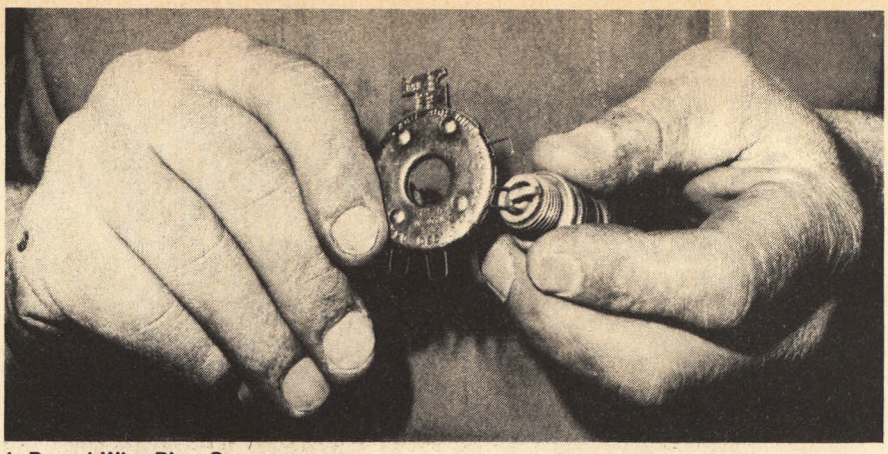
6. Most spark plug gap gauges have an electrode bender as part of the tool, to adjust the gap to specs by bending the side electrode.

7. When cleaning and gapping old plugs, you should pull back the side electrode so you can get a thin file in to file the center electrode flat.

Tuning Your Engine

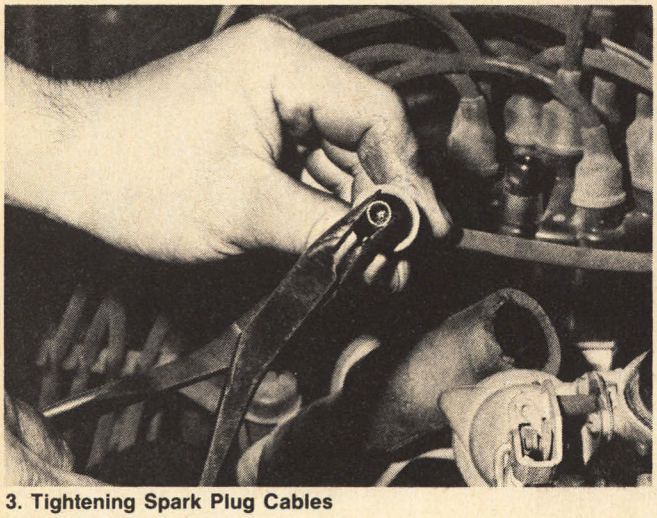
against the spring tension rather than backing away from it.

You must remember to adjust the initial timing after you adjust the dwell. Any change of point gap will change timing, so you must make your timing setting last. To check the timing, loosen the clamp bolt at the base of the distributor and turn the whole distributor while the engine is running to get the timing marks to line up under the timing light. The timing light must be hooked to No. 1 cylinder, of course, and the vacuum advance hose should be disconnected so that there is no chance for the vacuum to affect the initial timing. Also, you must have the engine speed at a normal idle. If the engine is idling too fast, the centrifugal advance will start to take over and your timing setting will be all out of whack. After the timing is set according to specifications, it's a good idea to make a final check of both centrifugal and vacuum advance by watching the timing marks under the light as you rev up the engine. Then the idle mixture and speed settings should be made. The carburetor should be checked to see if the choke is free. The choke unloader should be working properly. The fast idle mechanism should give the right speed, and the anti-stall dash pot—if it has one—should keep the engine from stalling when you let the

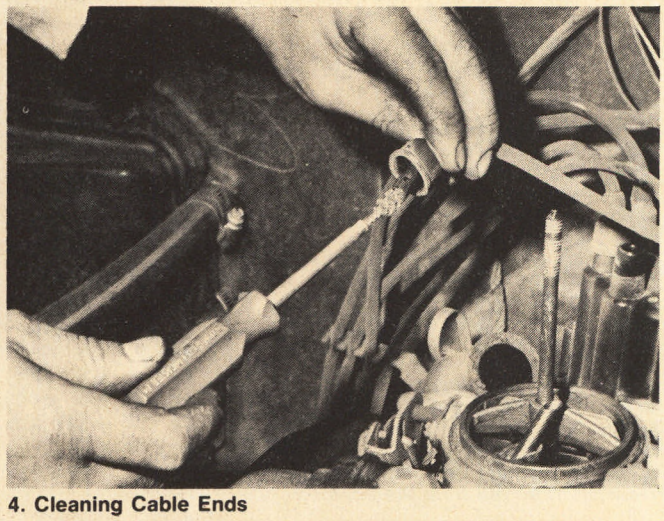


1. Round Wire Plug Gapper

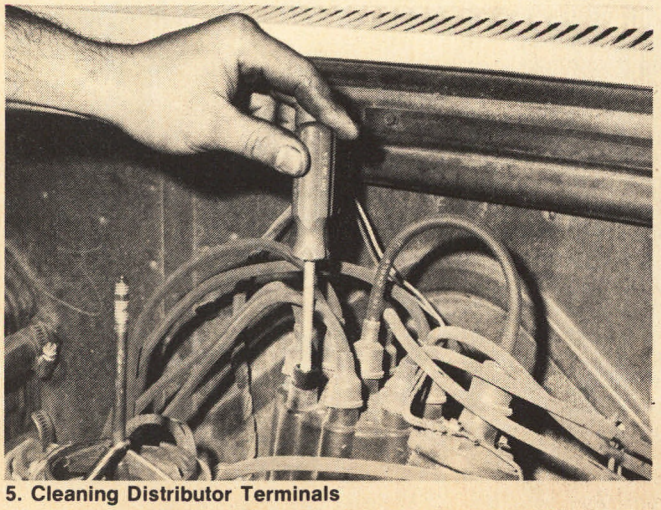
2. Hose for Starting Plugs



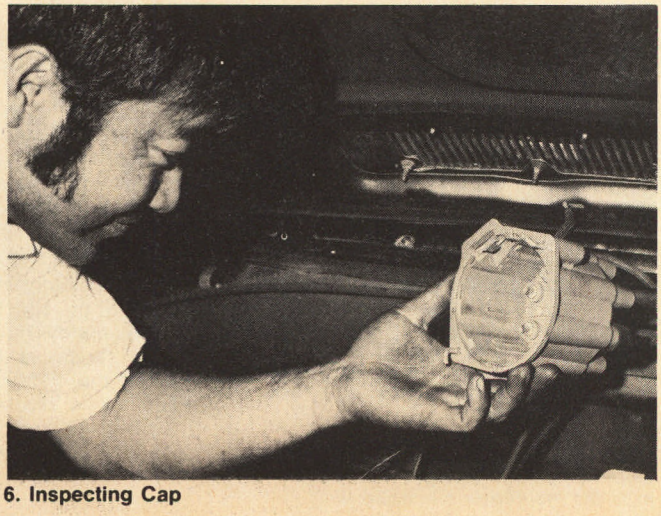
3. Tightening Spark Plug Cables



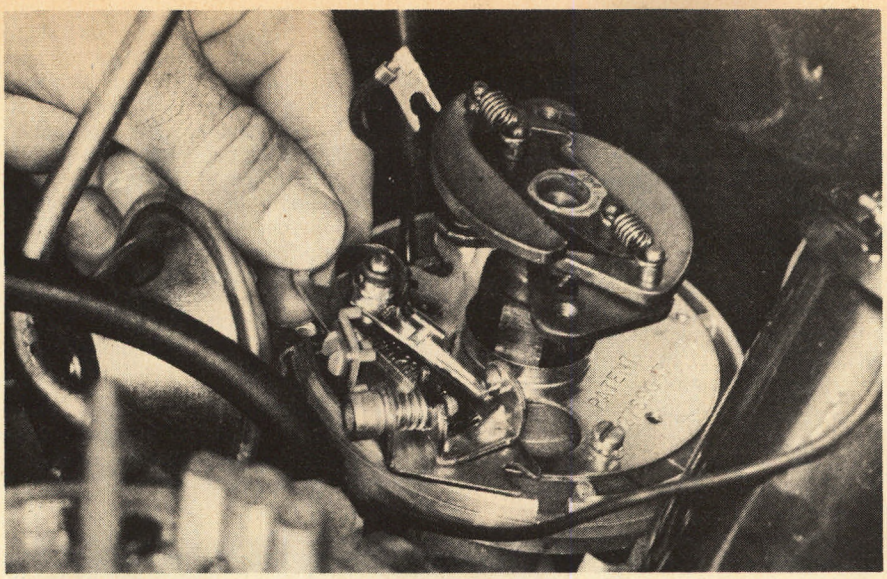
4. Cleaning Cable Ends



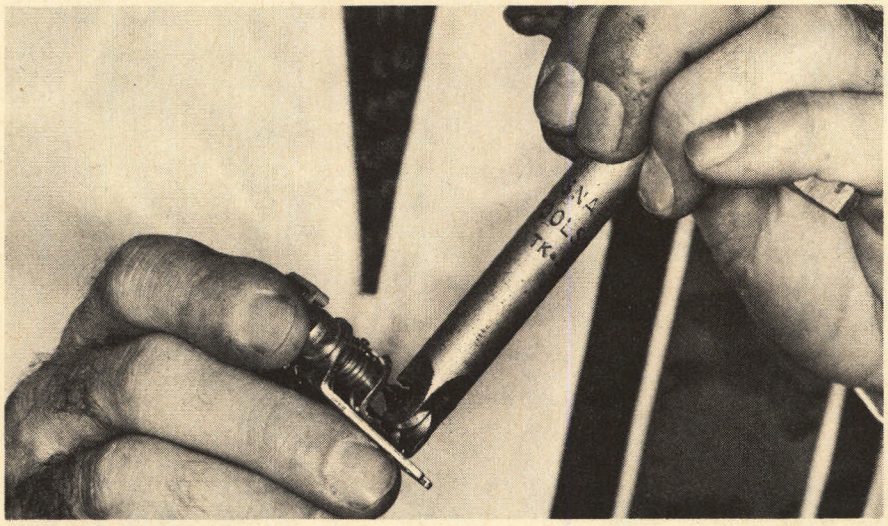
5. Cleaning Distributor Terminals



6. Inspecting Cap



7. Installing Points



8. Point Aligning Tool

throttle snap shut. Your basic tune-up is now complete.

Other tasks that are sometimes included at extra cost in the tune-up are an overhaul of the carburetor, a check of alternator output and voltage settings, a battery breakdown test, a starter draw test, an oscilloscope test of the ignition, a check of air/fuel ratio at the tailpipe, an exhaust emission test, and many other tests until you end up having everything on the car replaced except the hood ornament. A lot of the tests are good. We personally feel that an oscilloscope is the greatest thing since sliced bread, and a check of air/fuel ratio or emissions is the only way to go. But when you are working on your own car you have to be practical. You can't go out and buy $500 worth of equipment when you only have one car to work on. So what do you do if you want those other tests made? You go to a garage. That's what we'll talk about next.

HAVING A GARAGE TUNE-UP

The question most often asked is, "Where can I go to get a 'good' tune-up?" Unfortunately, there is no pat answer. It's difficult to recommend any particular place unless you have had some kind of personal contact with the establishment. And this is often impractical or impossible, especially when you have any number of different garages to choose from. Anyone who cares about his car wants to know that whoever works on it will be careful and dependable. Also that the price of repair is reasonable and that he won't be charged for unnecessary repairs or parts. So, the choice of a garage is very important.

The best way to narrow down the selection of garages and service stations is to ask friends and neighbors where they go for tune-ups and repairs and what they think of the work and service. The next step is to look over the work that was performed and see that it was done neatly and that the engine compartment was left clean. If they replaced the points, see if they cleaned the old grease off the distributor cam and then regreased it. It's a little thing, admittedly, but it's important if you want the job to be a lasting one.

At this point, if you have one or two shops in mind, visit them personally. Look over the work they're doing, what they have in the way of tools and equipment, and whether the shop is kept neat and clean. These are all important indications as to the type of work you can expect from this shop. If you're satisfied so far, the next step is to talk to the manager. See if he takes a genuine interest in you, your car and your problem. If so, this is a good place to start.

In almost every town there is always talk of an "old-timer" who can tell exactly what's the matter with your car as you turn into his driveway and before the turn indicator shuts off. In some cases this is true—though maybe not quite that fast. This fellow is the type who grew up with automobiles and never worked at anything else. He's been up against every problem there ever was and knows every part inside and out—mainly because in his time he has had to rebuild the parts himself. There was no such thing as inexpensive rebuilt parts, and to buy a new part was costly. And certainly, there was no electronic tune-up equipment. This type of person is fading out of the picture. Age, and the fact that labor is so expensive, make it cheaper to install a rebuilt or new part instead of fixing the old existing one.

The modern garage or repair shop of today is based on their mechanics' ability to tell what is wrong and replace the part. By this replacing of parts they can bring your car up to good running condition as usually defined by "factory specifications."

WHAT IS A DIAGNOSTIC CENTER?

A modern diagnostic center is a highly organized method of testing, checking

1. A flat feeler gauge may throw your gapping off, so the best gapper for plugs is the round wire type.

2. When reinstalling plugs in the engine, a short piece of rubber hose can be used to hold the plug while you start it into the threads. It's safer than starting them with wrench.

3. If the spark plug ends of your secondary ignition wires are loose on the plugs, you can get a better connection by tightening the ends with needle-nose pliers.

4. A small wire brush like this K-D #103 is useful in a tune-up for cleaning the ends of your spark plug cables and the terminals in your distributor cap.

5. Some tuners may miss possibility of corrosion buildup inside distributor cap terminals. This tool has wire brush on end for cleaning these hard-to-get-at places.

6. The inside of your distributor cap should be checked carefully for corrosion on the terminals or any carbon "tracks" around cracks.

7. Everyone can understand a spark plug replacement, but some amateur mechanics are wary of replacing their own points and condenser. It's not really that complicated, though.

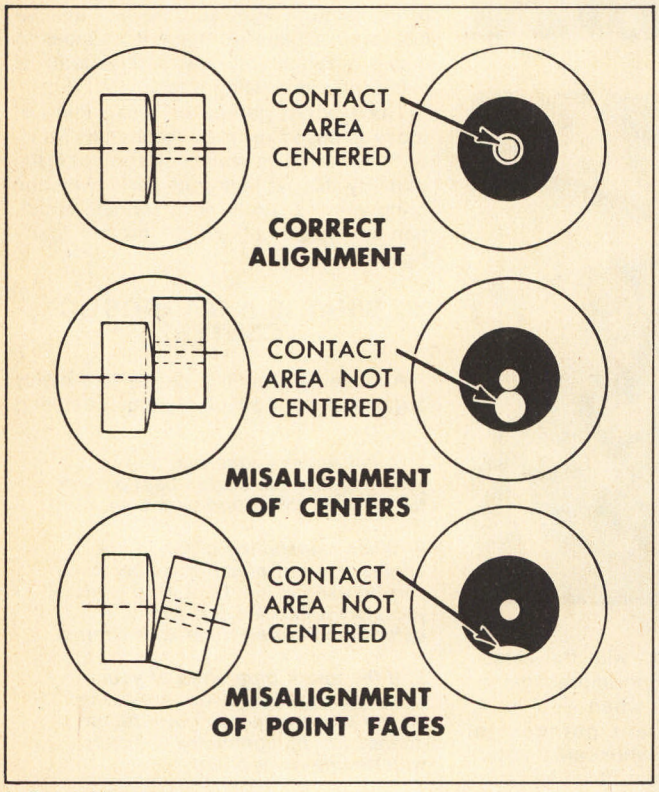
8. Proper alignment of the point arm is vital to a good tune, but you must remember you can only bend the stationary point, with a tool like this. The GM-type point like this can be adjusted off the car.

and analyzing every safety and performance factor of a motor vehicle. All tests are conducted with sophisticated electronic and dynamic equipment and instruments with a degree of accuracy never before attained in the servicing of automobiles.

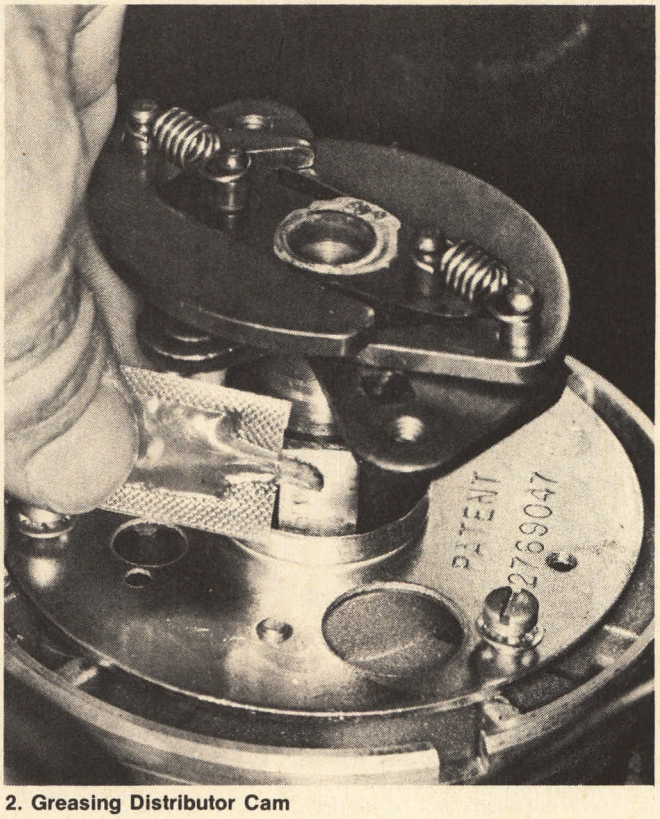
The first true diagnostic center was opened by Mobil Oil Co. in 1962. Since then, Mobil has expanded to more operations located in various parts of the U.S. Also in the intervening years, other major oil companies, automobile dealers and independent repair shops have opened diagnostic centers. And many more are in the planning or construction stages. A diagnostic center may be simple or elaborate—as small as one or two bays, or as large as a 6-station lane. However, the tests and inspections are common to all. Only the number of cars able to be checked during a given length of time changes with the size of the shop. You'll find it best to make an appointment in advance if you decide to have your car checked.

The most important service a diagnostic center does is to take the guesswork out of locating vehicle malfunctions. In difficult cases it can save you many more times the cost of the diagnosis. Basically, it tests a car through its complete speed and power range while it is hooked up to sensitive electronic gear. The chassis dynamometer can accurately simulate any type of road operating conditions such as acceleration, cruise, high speed and uphill pull. For instance, if you have a complaint of "missing" at 50 mph or poor acceleration, the trouble can be diagnosed accurately and quickly right in the shop and under almost the same conditions you experienced while driving your car on the road. An additional benefit of chassis dynamometer operation is that the complete driveline of the vehicle can be tested without leaving the shop. This includes clutch, transmission (manual or automatic) and differential.

Clayton Manufacturing Co., one of the leading manufacturers of chassis dynamometers, provides a vehicle Performance Guide chart to diagnostic centers

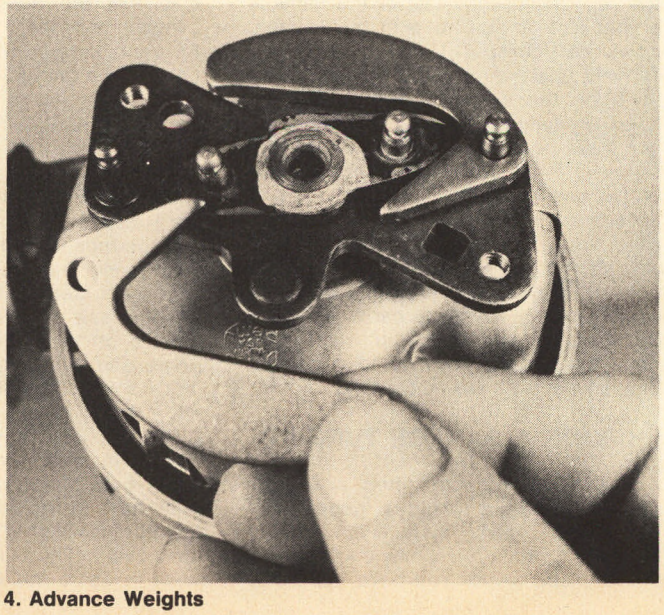


1. Point Alignment

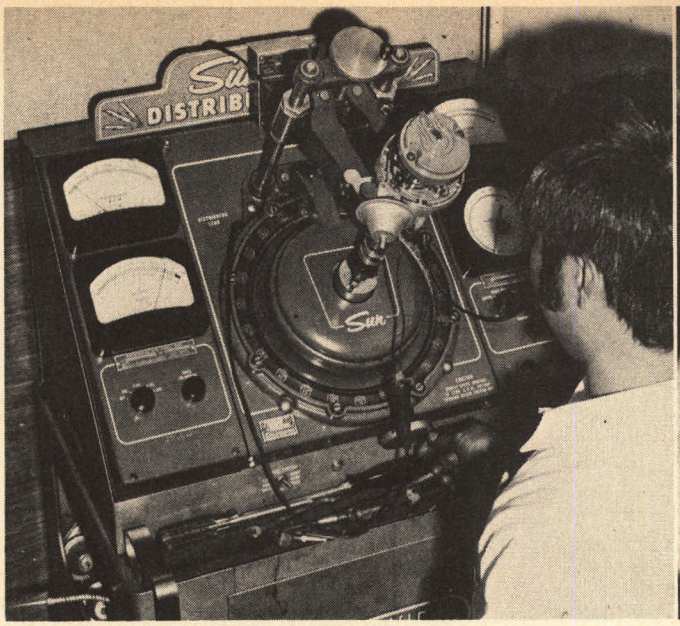


2. Greasing Distributor Cam

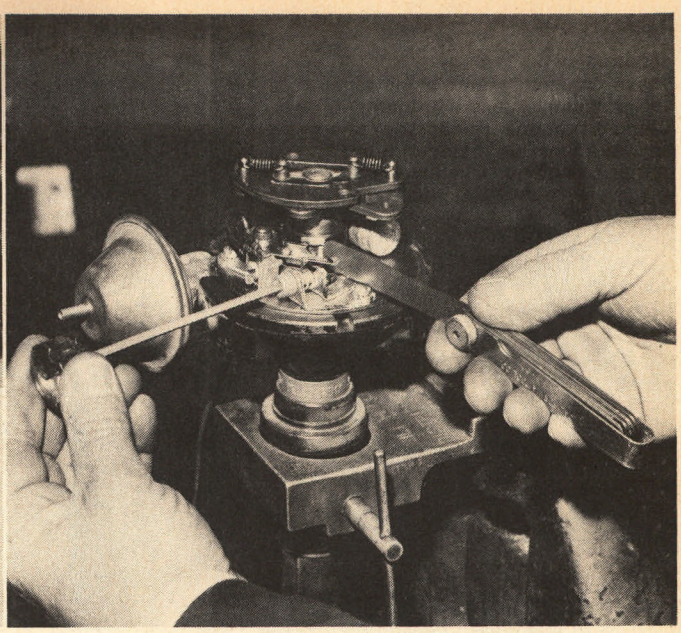
3. Greasing Distributor



4. Advance Weights



5. Distributor Testing Machine



6. Gapping Points

1. Getting the right alignment on the points assures that the contact pattern will be centered.

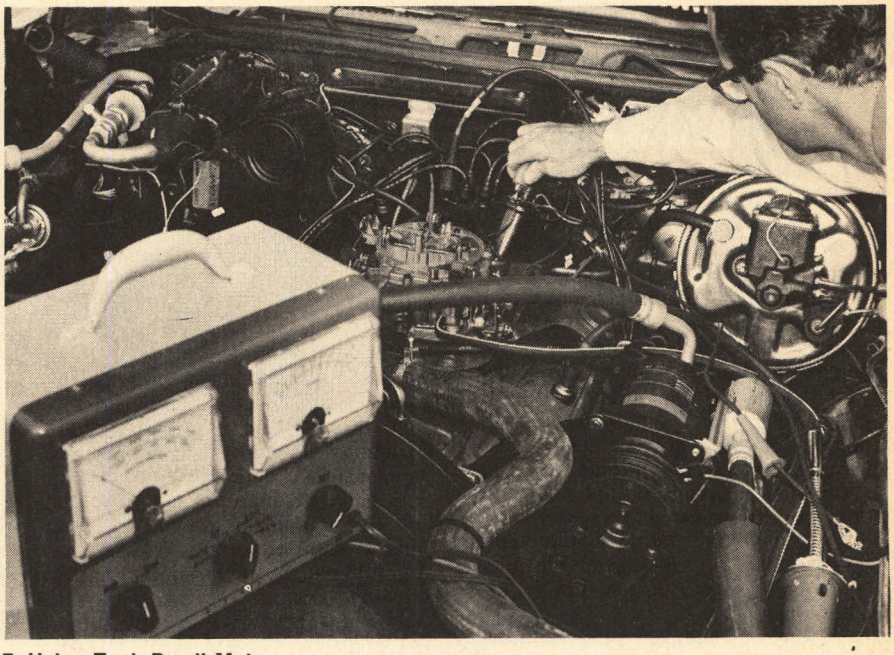
2. When installing new points, one spot you should be sure to lubricate with a small dab of grease is the distributor cam.

3. Other points that should get the clean 'n' lube treatment include the pivots for the advance weights.

4. For proper operation of the distributor, both the distributor cam and the centrifugal advance weights (the part being held up) should be cleaned of any rust or old grease.

5,6. Garages and tune-up shops use sophisticated gear for checking and adjusting distributors, but you can set points with just hand tools and a clean feeler gauge.

7. A portable instrument very handy for on-the-car testing is a tach and dwell meter, useful for setting idle and checking distributor dwell angle.



7. Using Tach-Dwell Meter

where their equipment is used. A diagnostic center will use this "road horsepower" guide as a "base line" with which to compare your car's performance. After a center has been in operation for a while, these guide charts may be changed due to geographic location. If a new car dealership performs many tests on one make, it gets to know these cars intimately and has very intimate guide lines. Also, the dealership technicians become highly skilled at testing and diagnosing a particular make. This is not to say, however, that an independent diagnostic center cannot do an equally good job.

Upon entering a diagnostic center, you will notice that it is a very clean, well organized and brightly lighted shop. Most centers are glass enclosed so you can see what is being done to your car. Moreover, you may find additional gauges in your viewing area which are duplicates of those being used by the technician. For the most part, the gauge readings may not mean much unless there is an audible description of just what is taking place at that particular time. Some centers have a speaker system, while others utilize a brief written description next to the gauge.

Do not get the idea that a diagnostic center is the same as a dyno tuning shop. Much of the equipment is similar and some of the tests are the same, but the big difference is in the work performed and the end results. The function of a diagnostic center is to work to factory specifications, and nothing more. Diagnostic center equipment tests and evaluates the performance of your car's engine and tells the operator what work needs to be done to return your car to a satisfactory operating condition as established by the manufacturer. In other words, plugs (gap and heat range), points (gap and dwell), coil, timing, advance, etc. are all set according to and checked for working to factory specifications. Nothing is altered internally, nor is there any deviation from the program of testing. As a rule, when this close-tolerance tune-up work is performed by a diagnostic center you should notice an improvement in performance, mainly because most cars are operating at a very minimal condition.

Diagnostic operations have been the center of considerable controversy since they started popping up everywhere. Small independent garagemen will tell you that the diagnostic center is a production line designed to sell parts and services, and that frequently the work done is not really needed at all.

Diagnostic center personnel, in turn, say that the small independent garageman does not have a dynamometer and other necessary equipment to make a complete test of your car.

The new car dealer then gets into the act by claiming that he is the only one who is in close touch with the factory and, therefore, he is the only one who knows how your car should run.

Tuning Your Engine

All of these factions are correct to a degree. Actually, it really doesn't matter where you take your car for service. What does matter is the honesty, capability and knowledge of the people who work on your car regardless of what type of establishment they work in. If you find a place that keeps your car in good condition, to your satisfaction, then stick with it—whether it is a 1-pump service station, an independent garage, a new car dealer, or a million dollar diagnostic center.

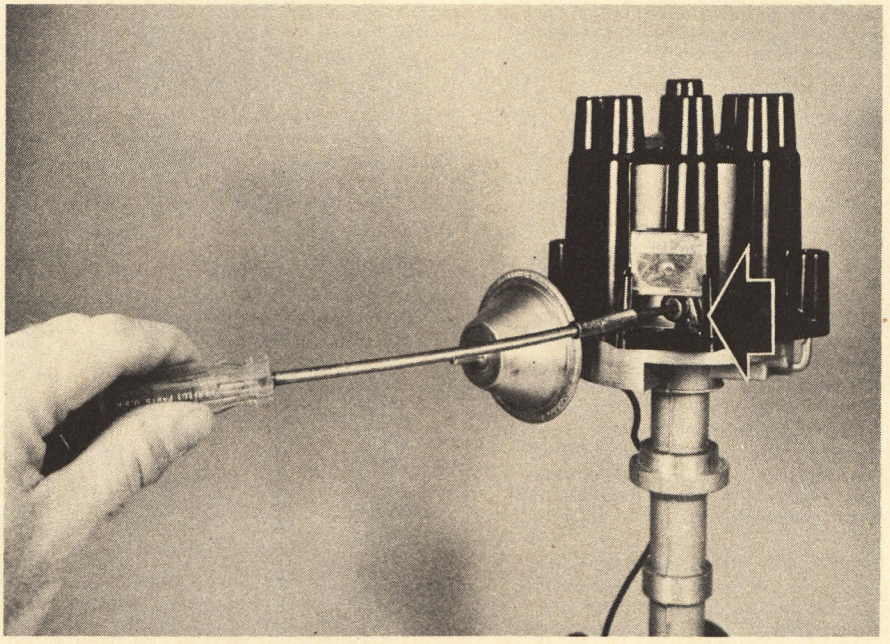
HOT ROD TUNE-UP

The old adage "If one's good, two's better and three's a gas" just isn't true in performance tuning any basically stock or near-stock engine. Today, in most cases, the factory stock parts are more than adequate in giving you all the horsepower that's on tap right up to 6500 rpm.

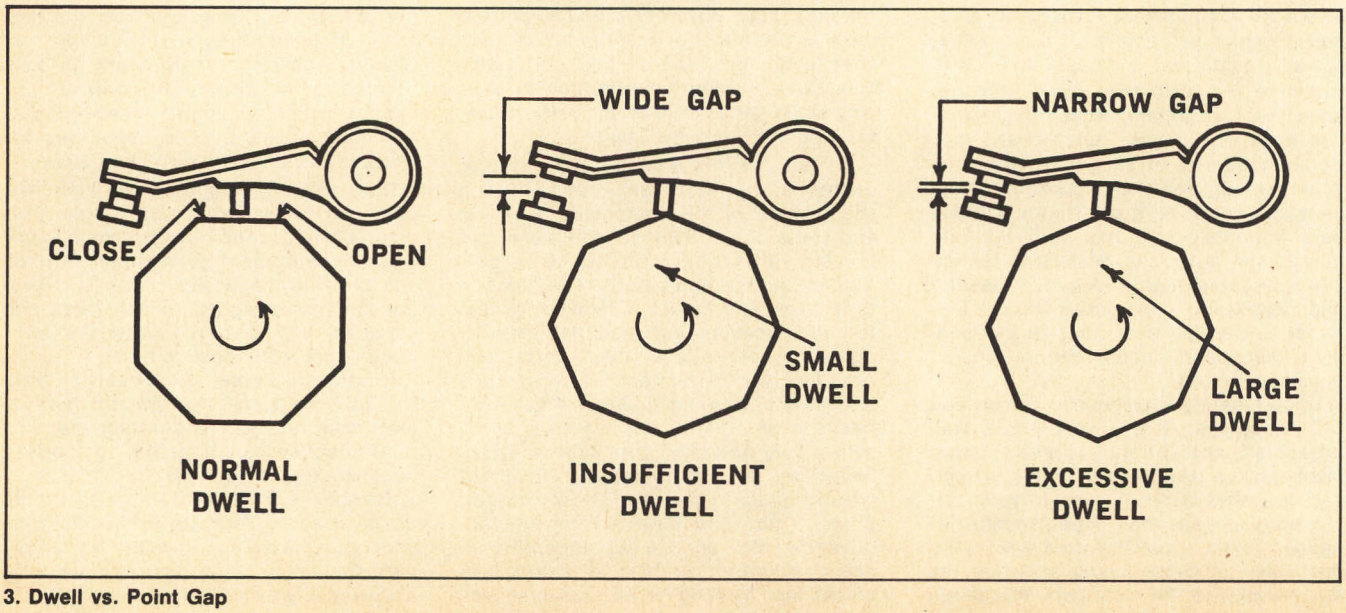
If you decide to modify your car, you should realize what you're getting into—not only from a standpoint of dirty hands but also from a legal angle. In some cases you may actually be breaking laws by modifying your car. A simple change from resistor-type spark plug wires to the solid metallic non resistor type could be in violation of a federal public law which states that in time of emergency, ignition radiation that interferes with radio or television broadcasts is illegal. That is why all of the car makers put resistor wires on new cars. Not that there is any law against the solid core wires, but the car makers do not want to be accused of contributing to a situation wherein all of the airplanes in the country might have trouble transmitting in case of a national emergency.

What about other modifications that affect the smog controls? In that case it presently depends upon your state law. The Federal emissions control legislation currently applies only to cars before they are first sold, except in certain specific

1. Handheld Meter



2. Adjusting GM Distributor



3. Dwell vs. Point Gap

instances that apply to new-car dealers only. However, if your state has passed no specific laws against modifications that would affect smog controls, you're on safe ground.

Some states (and California is an excellent example) have specific laws that make it illegal to do any modifications whatsoever that would affect emissions. This includes timing changes, carburetion changes or just about anything that you could do to the engine. If you live in a state that has such laws, it is your responsibility to find out if you're breaking the law.

There currently is no law against modifying your car for drag strip use or any other use that is off the public highways (it's only a matter of time before someone suggests it seriously). Presently, you can do anything that you want to on the drag strip to conform to strip or association rules just as long as you change it back to stock before you hit the road again.

The best thing you can do to your engine is experiment. Have you ever run .020-in. plug gaps? If you haven't, how do you know it isn't a good thing to do? Have you ever tried bigger jets or smaller jets? How about spark advance or initial timing? The only difference between you and Ed Pink is that Pink has tried everything in the world. He knows what will give more horsepower and what won't, so he sticks with the things that will.

In addition to experimenting, you must keep records. Write down everything you do to your car. Every change you make should be recorded, including the results of the change. Slowly, you will eliminate all the wrong guesses, and your car will start performing better. Sounds like a lot of work, doesn't it? We don't know a single lazy person who has ever made a car run well. Most tuners work around the clock, constantly searching for perfection. But they have the satisfaction of knowing they have made a car run well. We hope that you will experience that feeling too.

1. Handheld tach and dwell meters are relatively inexpensive at most auto parts stores and well within the reach of the "weekend" mechanic.

2. General Motors distributors from 1957 up have a "window" (arrow) through which points can be adjusted while the engine is running.

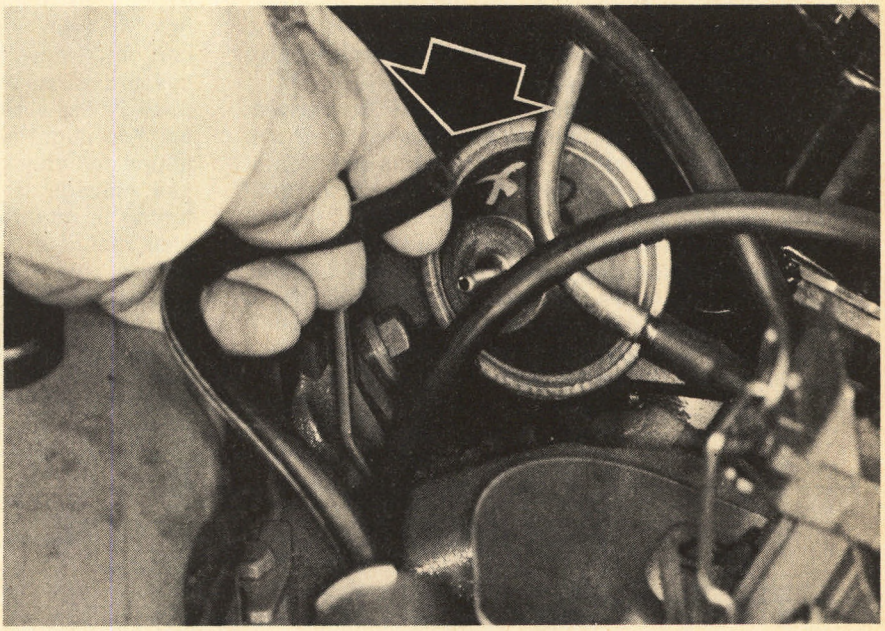
3. "Cam angle," "dwell," and "coil saturation" are all determined by the gap of the distributor's breaker points. Careful work with a flat feeler gauge or electronic dwell meter will set you up to specs.

4. When setting the timing, the idle speed should be set low enough so the centrifugal advance doesn't come in, and the vacuum line should be pulled from the distributor (arrow) and plugged with a pencil or wooden golf tee. This keeps vacuum advance at idle from influencing the setting.

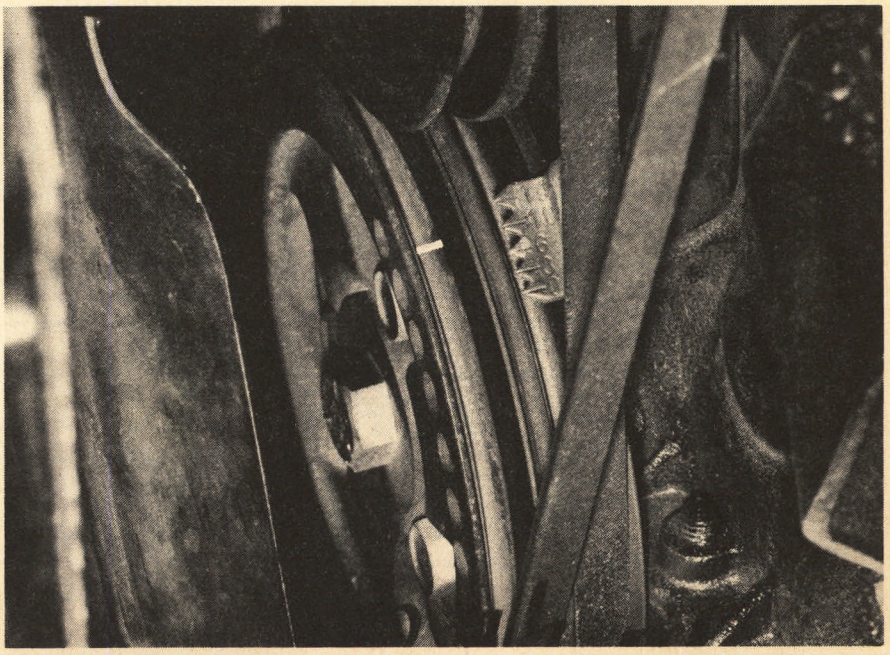
5. The timing marks on most engines consist of a stationary, degreed pointer somewhere on the block and a corresponding mark on the lower pulley. A power timing light is best for visibility of the marks, as you may have to wait until dark to get enough contrast when using the less expensive neon timing lights. Use yellow chalk to make marks stand out.

'72-73 VACUUM READINGS ARE LOWEST EVER

If you like to use a vacuum gauge for checking your engine, you are in for a surprise when you hook one up to a late-model car. For many years we have expected 18-21 ins. of hg. vacuum at idle. Anything less meant the valves were leaking, the rings were shot, or any of dozens of ailments. The only exceptions were high performance cars with a lot of overlap in the valve timing. In 1970 and '71, the retarded ignition timing, that was used to cut down on emissions, gave vacuum readings at idle of only 15 ins. of hg. on many cars. For '72, valve timing overlap was increased to control nitrogen oxide emissions, and some cars even recirculate the exhaust gas. The result is vacuum readings so low you won't believe your gauge. Many '72's and '73's idle at 13 ins. of hg. So if you check a late engine for idle vacuum and get a low reading, don't start tearing it down to do an overhaul until you check the vacuum above idle, or even while driving the car. You'll probably find that the vacuum is good at speeds above idle. If it isn't, make a compression test or cylinder leakage test to be sure the problem is really inside the engine before you tear it down.



4. Vacuum Advance Hose



5. Timing Marks

Underhood Maintenance Schedule

With the current focus on economy and air quality, it is increasingly important to properly maintain our increasingly complex automobiles. Model T fixit methods no longer apply. Instead, there are shop manuals, owners manuals and maintenance schedules. This book is aimed at helping the do-it-yourselfer keep his car humming the right tune while saving him money in the bargain—and without overtechnical instruction. Toward that same noble goal, we direct you to this general guide to underhood maintenance scheduling. While the other pages of this book tell you how to perform tune-up and maintenance services, this chart is designed to show you *when* they need to be done.

Much of your maintenance will be of the preventative type; that is, you should try to pinpoint potential trouble areas before they become problems, through regular maintentance and checks for fluid leaks, etc. Although the chart shows the important tune-up and service operations, what it doesn't show are the things you should do as frequently as once a month. At least once a month, you should make an underhood inspection for leaks and unusual sounds, and check the battery water level, radiator level, power steering fluid level and engine oil level. These checks can be made quickly and will become a matter of habit after awhile. This chart is a general one; more specific scheduling for your car can be found in either the owner's manual or the factory shop manual that applies to your car.

To use this chart, simply make a diagonal line through each box as a service check is performed. Where we have made one diagonal line in a box to indicate that this is when an operation should be done, *your* diagonal line will complete an X in the box. At every six-month interval in the life of your car, you'll have your basic underhood maintenance covered when all the applicable boxes have X's in them in the vertical column for that six-month period. You might also want to keep a notebook of gas fillups for checking gas mileage, because slipping gas mileage is an immediate warning that some tuning is required. In this same notebook, you can also record the dates and mileages that your own or the garage's service work was done. A well-maintained vehicle with a complete file of all service records is your assurance of top resale value when it comes time to sell.

UNDERHOOD MAINTENANCE SCHEDULE

SERVICE OR CHECK	Number of Months, or Thousands of Miles, whichever comes first							
	6	12	18	24	30	36	42	48
Change engine oil, change filter every second oil change (optional: oil change 3 Mos. or 4000 miles)	/	/	/	/	/	/	/	/
Cooling system pressure test, check hoses and cap		/		/		/		/
Flush cooling system, install new hoses and antifreeze				/				/
Clean carburetor air filter		/		/		/		/
Replace air filter				/				/
Replace fuel filter		/		/		/		/
Inspect, test, adjust: point dwell, timing, ignition wiring, replace parts as required		/		/		/		/
Check spark plugs, replace if needed, (leaded fuels)	/	/	/	/	/	/	/	/
Adjust idle speed, fast idle and carburetor solenoids		/		/		/		/
Check, lube throttle linkage and check choke shaft operation		/		/		/		/
Check, service fuel vapor system		/		/		/		/
Replace filter in vapor canister				/				/
Check PCV system, hoses		/		/		/		/
Replace PCV valve				/				/
Check air conditioning system hoses, check R-12 charge at sight plug	/	/	/	/	/	/	/	/
Check drive belt tension, adjust or replace belts as necessary	/	/	/	/	/	/	/	/

ENGINE STALLS

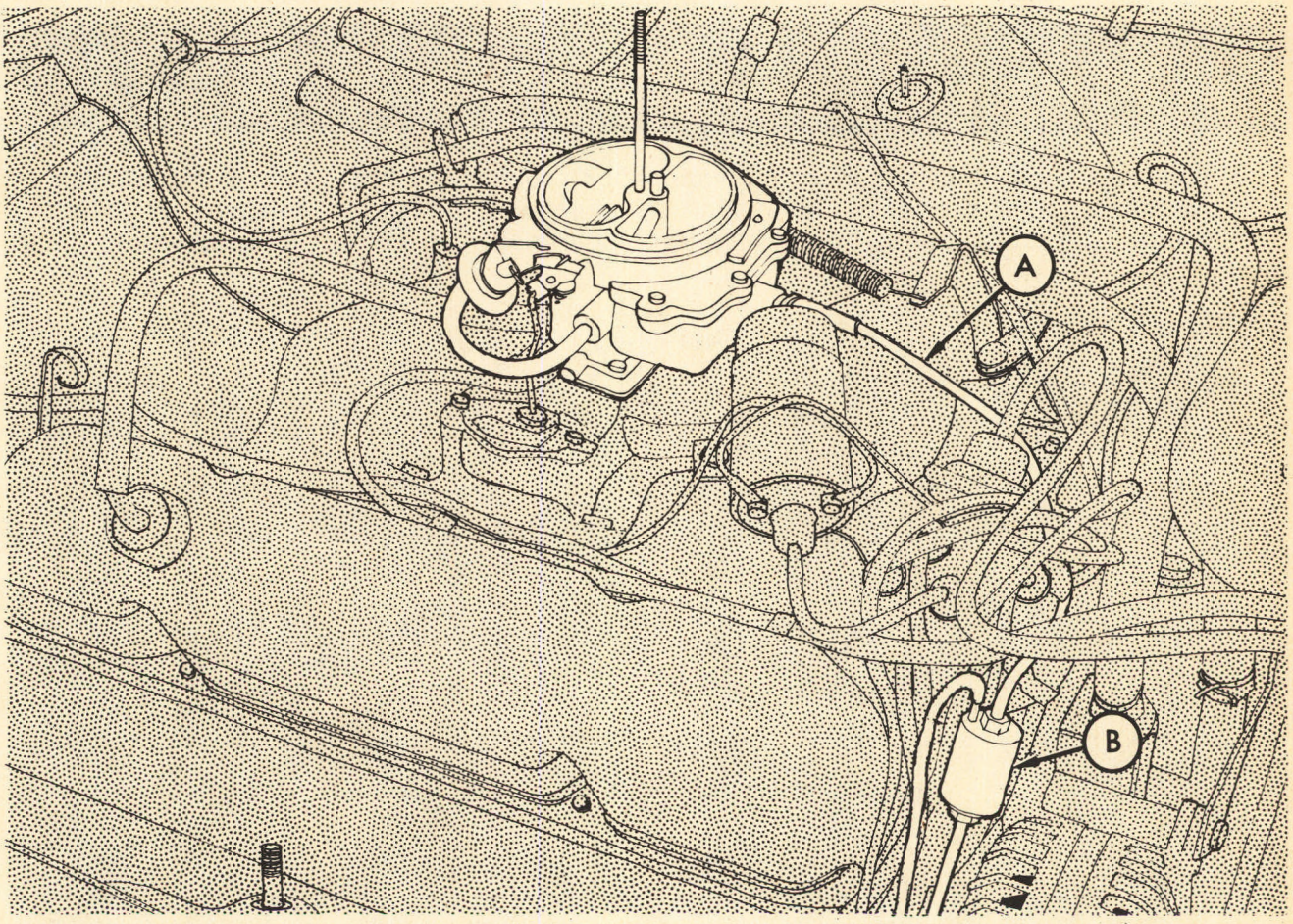
Engine "stalling" (stopping at idle or when the car is first put in motion) can result from several conditions. Often troubleshooting the problem as an engine idle problem will correct the stalling situation. The list below contains the standard situations you are likely to run into.

IDLE SPEED TOO LOW: When a running automobile engine is suddenly required to put the entire weight of the automobile into motion, a tremendous load is placed on the engine. If the engine speed is not high enough, it may be more than the engine can handle and it will stall.

To remedy the problem of low idle speed—idle speed should be approximately 400 to 750 rpm (revolutions per minute) or higher for some car models—locate the idle adjustment screw on the carburetor (refer to the shop manual or the owner's manual for exact location). Using a screwdriver, adjust the idle speed to the desired rpm.

Idle speed can be set by ear, or if you want to establish the exact idle speed, a tachometer (engine speed indicator) can be used.

IGNITION POINTS: Worn, burned or badly adjusted ignition points can cause idle problems. See Petersen's BASIC IGNITION AND ELECTRICAL SYSTEMS.



VAPOR LOCK: This is an engine stall condition brought on by the overheating of the fuel lines and carburetor. If the temperature goes too high in the engine compartment, the fuel will change from a liquid to a vapor. This can form a vapor bubble in the line (A) between the fuel pump and the carburetor, shutting off the flow of fuel into the carburetor float bowl.

NOTE: MANY LATE MODEL CARS, ESPECIALLY THOSE WITH AIR CONDITIONING, ARE EQUIPPED WITH A DEVICE CALLED A VAPOR BYPASS SYSTEM. THIS IS A SPECIAL FUEL FILTER (B) WHICH HAS A METERED VENT IN THE TOP. ANY VAPOR THAT FORMS IS BLED OFF TO THE OUTSIDE AIR, REMOVING THE RESTRICTION IN THE FUEL LINES. IF YOUR CAR VAPOR LOCKS AND IT IS EQUIPPED WITH THIS FILTER, EXAMINE IT TO MAKE SURE THAT THE VENT IS NOT PLUGGED.

ENGINE STALLS

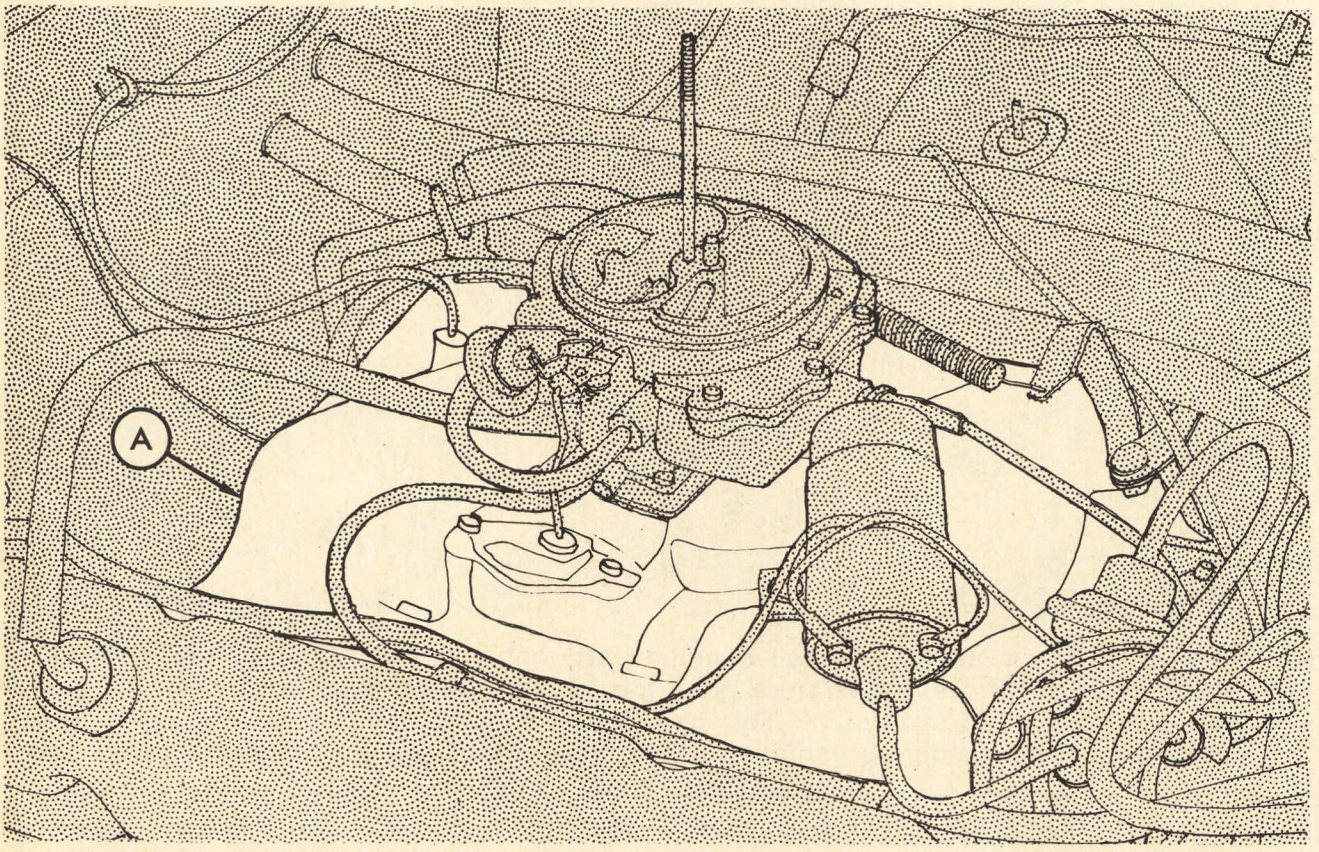
NOTE: THE TEMPERATURE GAUGE WILL NOT ALWAYS SHOW THAT THE ENGINE IS RUNNING EXCESSIVELY HOT. UNDERHOOD TEMPERATURES CAN BE VERY HIGH ON HOT DAYS WITHOUT THE INTERNAL TEMPERATURE OF THE ENGINE REACHING THE INDICATED CRITICAL POINT.

Vapor lock is most common on hot days and when the engine is being worked hard, as in climbing a steep grade, towing a trailer or other heavy loads or crawling along in heavy traffic for long periods of time. Usually the onset of vapor lock will cause engine surging (engine power increases and decreases at odd intervals). If things get bad enough, the engine will stall. The symptoms are exactly like running out of gas, which is actually the case. The carburetor *is* out of gas; the lines are blocked with a vapor bubble.

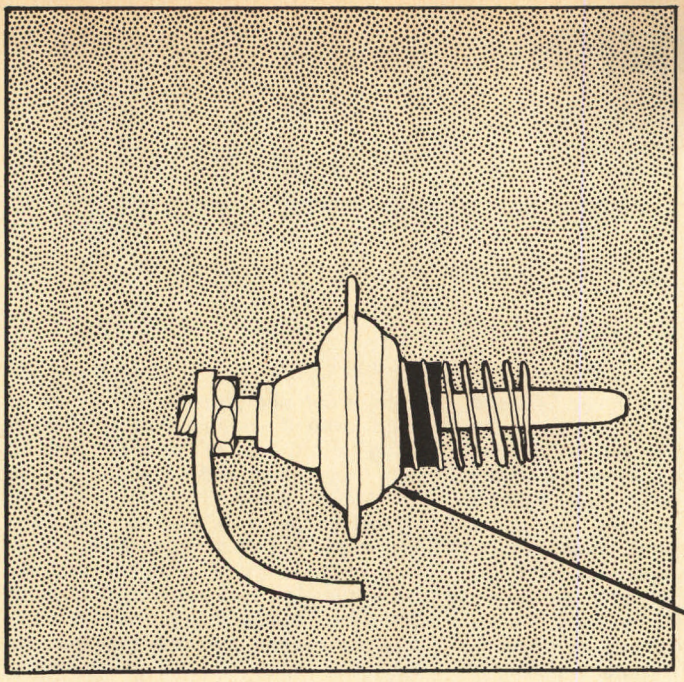
Correcting a vapor lock is simple. Just let the temperature under the hood fall below the point at which it vaporizes gasoline and the vapor lock will disappear. You can speed this process by opening the hood and applying a small amount of cool water to the fuel lines, fuel pump and outside the carburetor (do not get water in the carburetor opening).

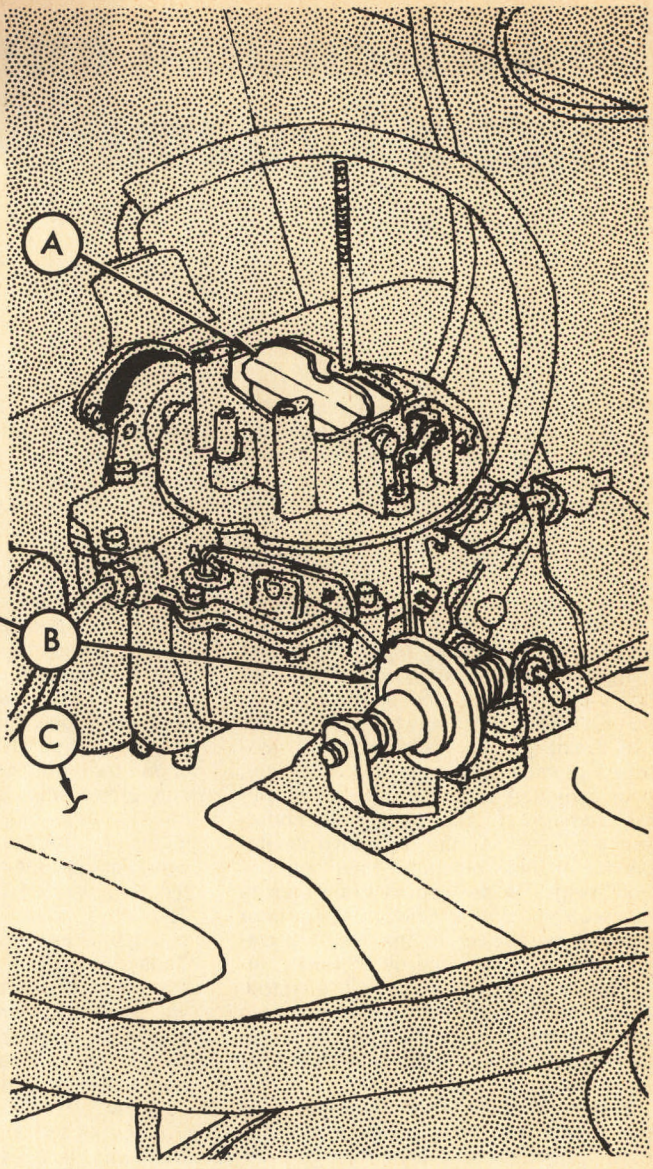
CAUTION: DO NOT SOAK A HOT ENGINE IN COOL WATER OR YOU MIGHT CRACK THE ENGINE BLOCK (DUE TO SUDDEN TEMPERATURE CHANGE).

If you have a car that is plagued by vapor lock problems in hot weather, the addition of some form of heat-sink or insulation (such as aluminum foil and clothespins or asbestos cloth) around the fuel lines inside the engine compartment can correct the problem to some degree.



VACUUM LEAK: A vacuum leak in the engine intake manifold (A) can cause irregular idle and stalling. A good example of this would be a windshield wiper hose or vacuum ignition advance line that has become disconnected or broken. A close visual check can often determine the source of the trouble. If not, there are several procedures for finding a vacuum leak, but they require some shop tools and a shop manual to remedy the problem.





DASHPOT: The dashpot, or throttle stop modulator (B), is a device used on many cars from 1969 to the present and on some pre-1969 cars with automatic transmissions. It is an electrically operated solenoid connected to the throttle linkage. The dashpot maintains a normal idle speed as long as the ignition switch is on and the engine is running. It decreases the idle speed setting (with throttle in completely closed position) several hundred rpm when the ignition is turned off to prevent the engine from dieseling (continuing to run after the engine has been stopped).

If the dashpot is not working, it can lower the idle speed below that required for normal operation and the engine will stall.

To check for proper dashpot operation, start the engine and hold the idle speed high enough so that the engine runs normally. You can do this either by having someone press on the gas pedal while you watch the dashpot or by operating the throttle linkage near the carburetor by hand. Turn the ignition off while watching the dashpot. If it is working, you should be able to see the throttle stop retract suddenly as the ignition is turned off.

If the dashpot is not working, replace it. Adjustment of the dashpot is covered in the chapter on fuel systems.

FLOODING: This is too much fuel inside the intake manifold (C). Flooding destroys the proper ratio of air to fuel and prevents the engine from working correctly.

The normal causes of flooding are: a defective float or needle and seat in the float bowl; overchoking, in which case the engine is not getting enough air; or percolation, in which the heat from the engine boils the gas in the carburetor after the engine is turned off.

NOTE: PERCOLATION IS A FORM OF VAPOR LOCK.

These problems can be checked for in two ways. First, remove the air cleaner and look into the carburetor venturi (A) to detect the presence of raw (liquid) fuel inside the carburetor or down inside the intake manifold. Next, remove one or more spark plugs and examine them to see if they are wet. If the plug is coated with raw fuel, the engine is flooded.

Flooding can sometimes be overcome by pressing the gas pedal all the way to the floorboard and holding it there while operating the starter. Under no circumstances should the gas pedal be pumped. The pumping action will simply add more raw fuel to the intake manifold. Another method of overcoming flooding is to remove the air cleaner and blow into the carburetor venturi (A). This will help remove excess fuel that has built up in the carburetor and intake manifold.

Understanding Emission Control Systems

During the past decade, the automobile has become a political football and it seems that almost everyone who has some kind of axe to grind (and there are many who do) has taken up the cudgel against Henry's greatest achievement. Safety experts condemn it, and so the government moves with a heavy hand into automotive design; pollution authorities blame it for the ever-increasing black cloud that hangs ominously over much of the nation's urban areas, and so the government dictates by *fiat* what the engine can discharge into the atmosphere. Motorists grumble about the lack of power, poor operation, and increased amount of fuel required to run each new-model-year's engines. As the legislative timetable for engine "cleanup" runs out, Detroit hedges in seeking new answers to the problem, and a California legislator seeking an answer to the recently discovered national energy "crisis" introduces a measure that, if enacted, would require each auto manufacturer to not only meet his state's emission requirements but also guarantee the owner a minimum of 15 mpg.

While the whole world seems to have gone mad, the smog problem worsens every year despite everything that's being done to control it. Smog first started in Los Angeles, but now there's eye irritation to some extent in all large (and many small) cities in the United States. It affects our breathing and can even cause death. Scientists tell us that the country loses millions every year from damage to plants and farm animals caused by smog. Whether you agree with their analysis that a photochemical reaction in sunlight between hydrocarbons and oxides of nitrogen that come out of the automobile crankcase and exhaust pipe is the main cause of smog (and many don't), the important thing is that laws have been passed to control such emissions from cars.

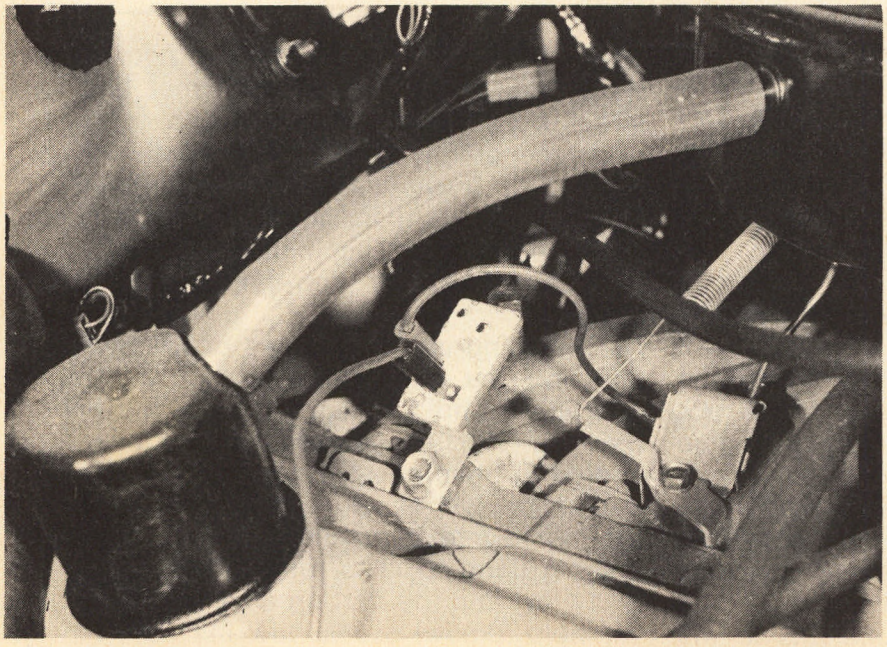
The average driver who never looks under the hood of his/her car isn't too concerned about the matter because he/she leaves such problems up to a mechanic. But the hot rodder and those who work on their own cars must study the law, understand it, and abide by it. The days when engine modifications could be freely made are gone forever. Today, you must know the federal and state laws that apply where you live and you must also comply with them. And if you make an engine modification that's illegal, you can be fined or denied a renewal of your license plates or tabs for your car.

Since all this smog business began in California, let's examine the situation in that state. If you live outside California, don't make the mistake of thinking that the same thing can't happen in your state. It can and probably will sooner or later, even if you have never shed a smog-caused tear or seen the kind of ugly brown haze that settles across the Los Angeles Basin.

Most people think that the only thing that blows out of an automobile crankcase breather is oil smoke, but that's not quite true. The hydrocarbons that cause smog are basically unburned gasoline and are emitted from the breather and the car's tailpipe. So let's take a look at crankcase devices to begin with, then we'll get into exhaust controls proper.

No piston ring has ever been manufactured that provides a positive seal between the piston and the cylinder wall; they all leak, even when brand new. Prove it to yourself by screwing an ordinary pressure gauge (without the valve) into the spark plug hole. Crank the engine over until the piston is on TDC at the end of the compression stroke, then stop. The pressure rises as the piston goes up, reaching a maximum at the top of the stroke. Now watch the pressure gauge after the piston stops and you'll see that it only takes a few seconds for the pressure to leak away. And where does it go? Between the cylinder wall and rings, that's where. When the engine is running, this leakage takes place fast enough to build up pressure in the crankcase.

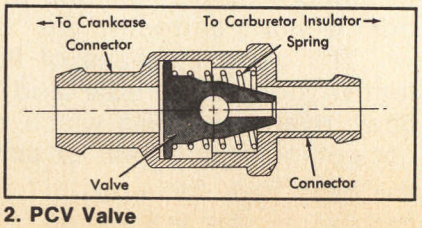
It happens because the combustion in the chamber doesn't burn all of the fuel; most of the time, it only burns that which is atomized. The remainder clings to the combustion chamber sides and cylinder walls, and so it doesn't burn. More spe-



1. Closed Crankcase System

1. Hose connecting air cleaner to rocker cover identifies this as a closed crankcase ventilation system.

2. When the spring-loaded PCV valve is in closed position (shown), engine is either off or in vacuum situation. As vacuum increases, valve moves against spring to allow flow. Spring must be tailored to fit a particular engine, as some pull more vacuum than others; you need correct smog valve if your engine is to idle right.



2. PCV Valve

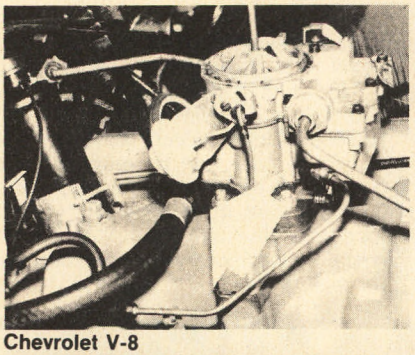
cifically, the fuel gets into that small space between the top of the piston and the cylinder wall.

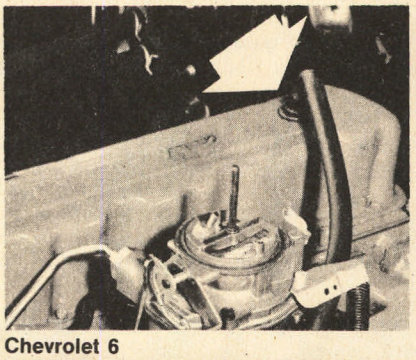
When combustion takes place, the force of the burning gases pushes the piston down to make everything work, but that same force also pushes the unburned fuel down past the rings and into the crankcase. A scientific analysis of these blowby gases has found them to be mainly unburned gasoline. Now, if this unburned gas was allowed to build up in the oil pan, it's easy to visualize what would happen. Before long, the oil would contain so much gasoline that it would no longer work as a lubricant. These blowby gases are also responsible for the varnish, sludge, and acid that begins to eat at the bearing metal.

Automotive engineers recognized the problem long before the politicians discovered smog, and they tried to get the vapors out of the crankcase, but without too much success. To do this, almost every manufacturer settled on a road draft system. A tube connected to the crankcase extended below it so that the draft of air flowing underneath the car would create a slight suction at the end of the tube, drawing the vapors out of the crankcase. Naturally, there has to be a hole somewhere else on the engine where fresh air can enter. This was usually placed in the oil filler cap and there was some kind of an oil-wetted mesh inside the cap to keep dust out of the engine.

As long as the car was traveling fast enough to cause a draft on the tube, the system worked pretty well, but at speeds below 25 mph, it didn't work at all, other than to let the crankcase vent itself just from pressure of the gases. Delivery trucks went for days without ever going over 25 mph but they weren't alone with the problem; boats had their share of problems too. It's a little difficult to create a road draft when you don't even

Typical PCV Valve Locations


Chevrolet V-8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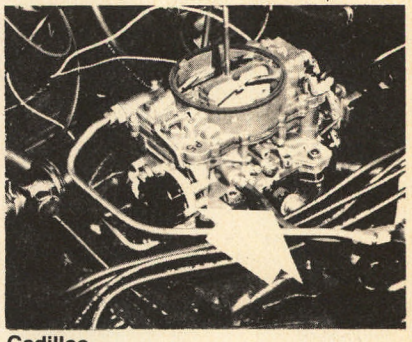
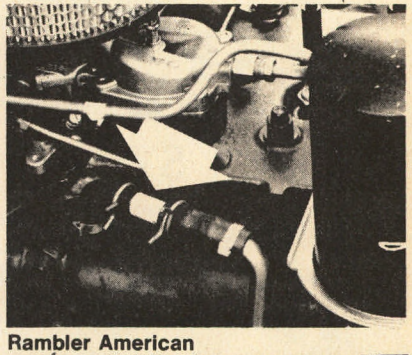
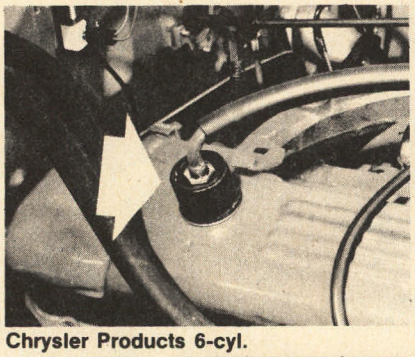
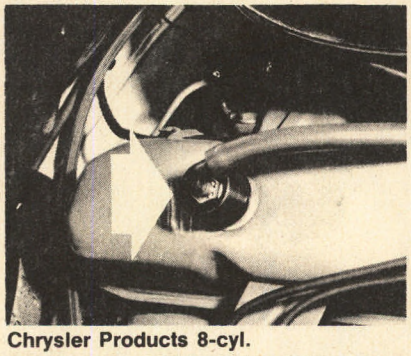

Cadillac

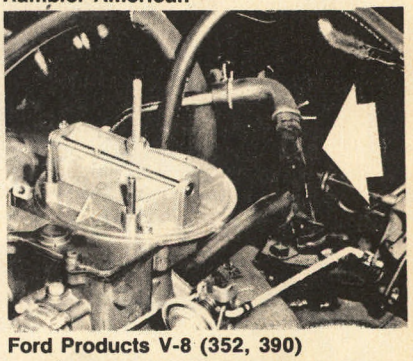
Pontiac

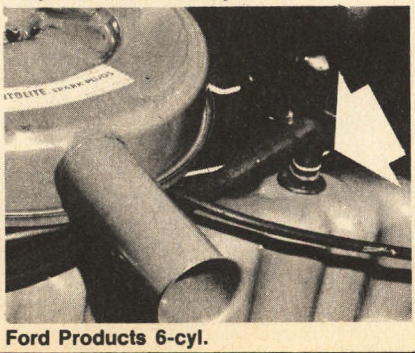
Buick


Rambler American


Chrysler Products 6-cyl.


Chrysler Products 8-cyl.


Ford Products V-8 (352, 390)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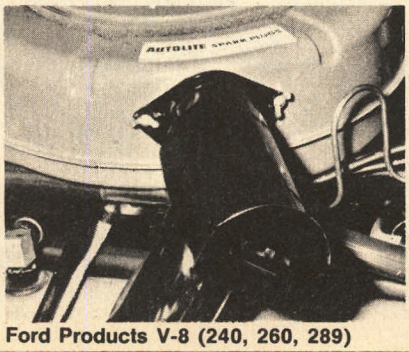
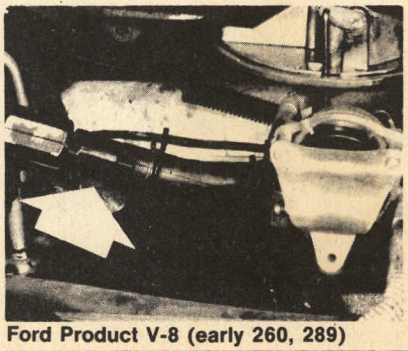


Ford Products V-8 (240, 260, 289)


Ford Product V-8 (early 260, 289)

have a road on which to travel. So, the problem is not really new—positive crankcase ventilators of various types have been used for many years on vehicles operating under such special conditions.

CRANKCASE DEVICES

There are four types of crankcase devices, usually called PCV (Positive Crankcase Ventilation) systems. In all PCV systems, the road draft tube is either nonexistent or plugged. Type 1 has a hose running from the crankcase through a valve to the intake manifold. Manifold vacuum sucks the vapors out of the crankcase and into the intake manifold where they are carried into the combustion chamber and burned, with fresh air entering through the oil filler cap. The vacuum connection to the crankcase does not necessarily have to be directly on the crankcase; it can be practically anywhere on the engine depending upon how the system was designed. But regardless of where it's located, the purpose is the same.

In a Type 1 system, the PCV valve can have either a fixed orifice or a spring-loaded plunger. Six-cylinder engines usually have the fixed orifice, and V-8's have the plunger. If the engine has an intake manifold explosion or "backfire," the spring plus the force of the backfire closes the valve to prevent flame from getting into the crankcase and causing an explosion. But when the engine is under high-vacuum conditions such as idle or deceleration, the plunger moves against spring pressure to a minimum flow position. And when the engine is under low vacuum or a partial load, the spring moves the plunger to a central position for maximum flow.

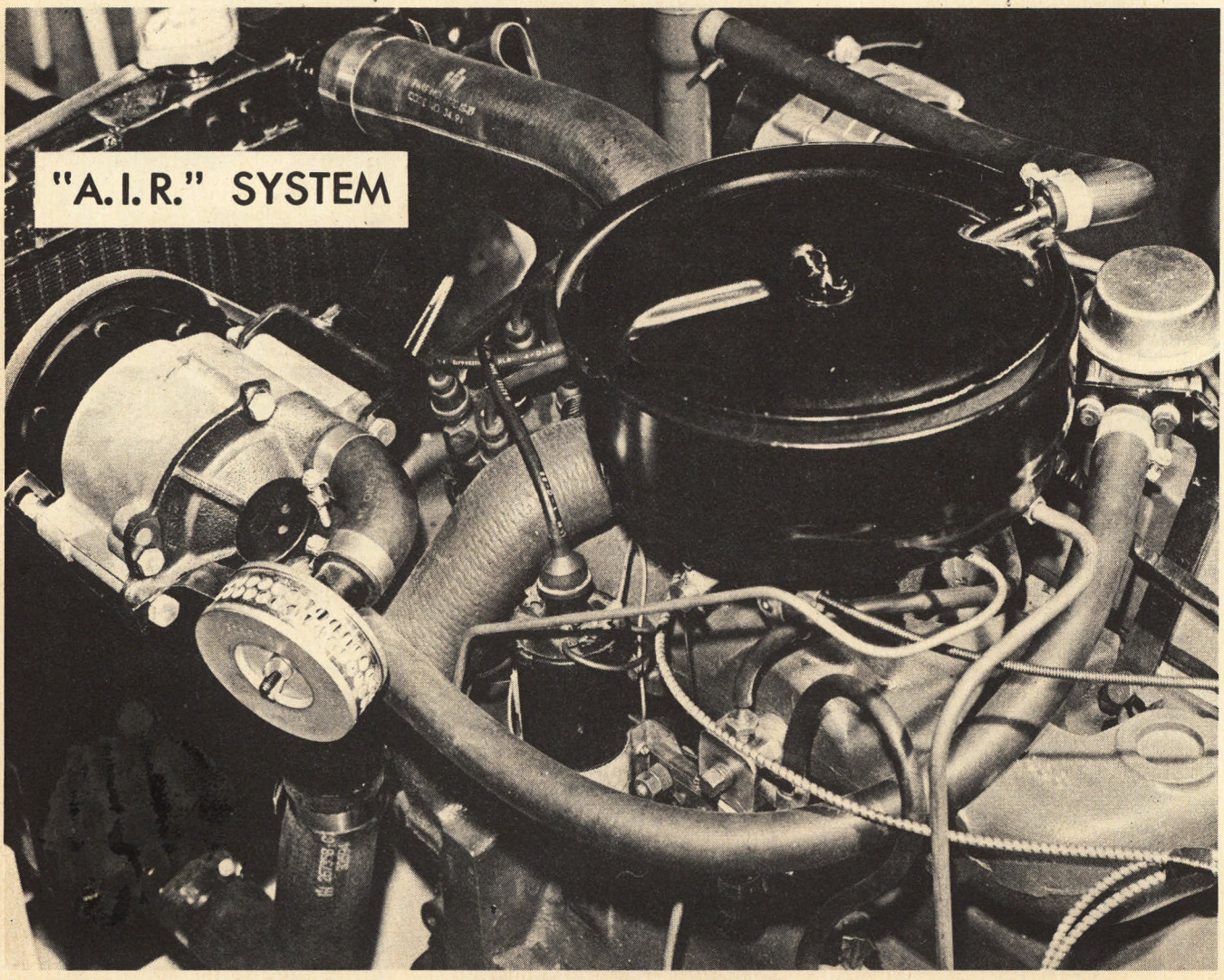
Under wide-open throttle conditions with zero vacuum, the spring closes the valve, but the blowby gases are still sailing past the rings into the crankcase. The only place they can go under this condition is out through the oil filler cap. The same thing happens on the fixed orifice system, since there's no vacuum to draw the gases into the intake manifold. So Type 1 is not perfect, because it allows the gases to escape into the air at zero vacuum.

Much the same as Type 1, the Type 2 system uses a special PCV valve and oil filler cap. The valve is a diaphragm type that regulates the amount of flow according to crankcase vacuum. If the crankcase is under pressure most of the time (as it would be on a worn engine), the valve opens up to take care of the blowby gases.

The Type 2 oil filler cap uses a calibrated hole, large enough to let in fresh air but small enough to keep the crankcase under vacuum. Type 2 systems can be installed only on engines with a "tight" crankcase, as any leaks that allow air to enter the crankcase will cause the valve to open wide, creating a condition that may lean the fuel mixture to a dangerous level.

Type 3 is the same kind of breather that home mechanics have used for years to cure a bad case of excessive crankcase smoking. It's simply a tube from the crankcase to the air cleaner that lets fresh air enter the engine via the oil filler cap, through the tube into the carburetor and then into the engine. Since blowby gases are mainly unburned gas, this system tends to richen the mixture, a fact that must be taken into account when designing the carb.

Type 4 is a combination of Types 1 and 3, and it's sometimes called a CCV (Closed Crankcase Ventilation) system. A sealed oil filler cap prevents crankcase gases from escaping under zero vacuum conditions as it would with Type 1. A tube from the air cleaner goes to the rocker cover, carrying fresh air down



1. A.I.R. System

1. Everyone complained about the complexity of "plumbing" on this early air-injection system, not realizing that this rather simple system was just the beginning.

2. Anti-backfire valve is controlled by engine vacuum. When engine is decelerating at high vacuum, anti-backfire valve is actuated and relieves pump pressure so that no air is pumped into exhaust manifold.

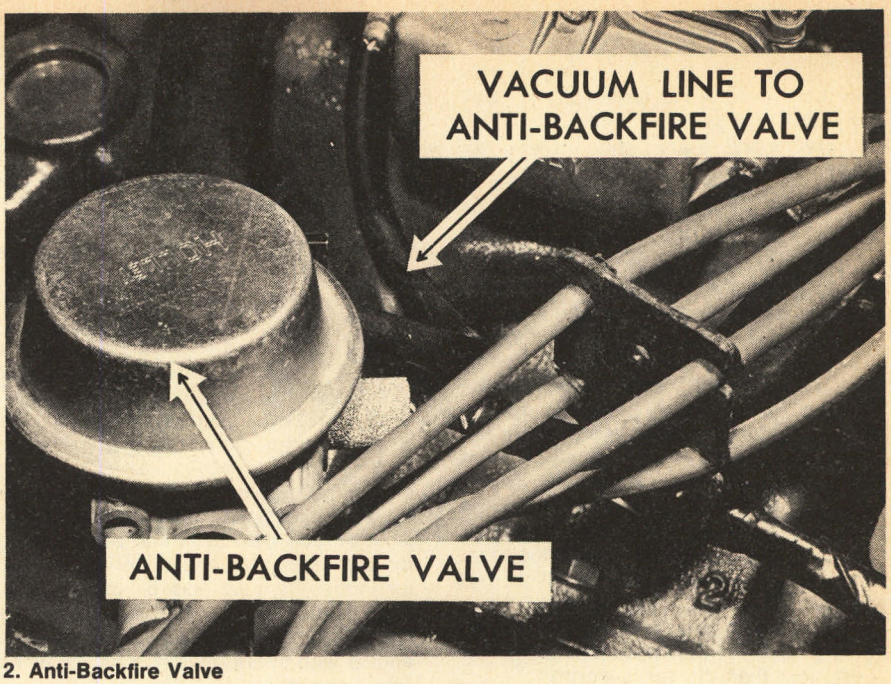
3. Some early air pumps used a large external filter to help muffle the noise of air pump operation as well as filter incoming air.

4. Late-model air pumps use a diverter valve to prevent excessive system pressure from causing a backfire. Filter is an integral part of pump on this Delco unit (arrow).

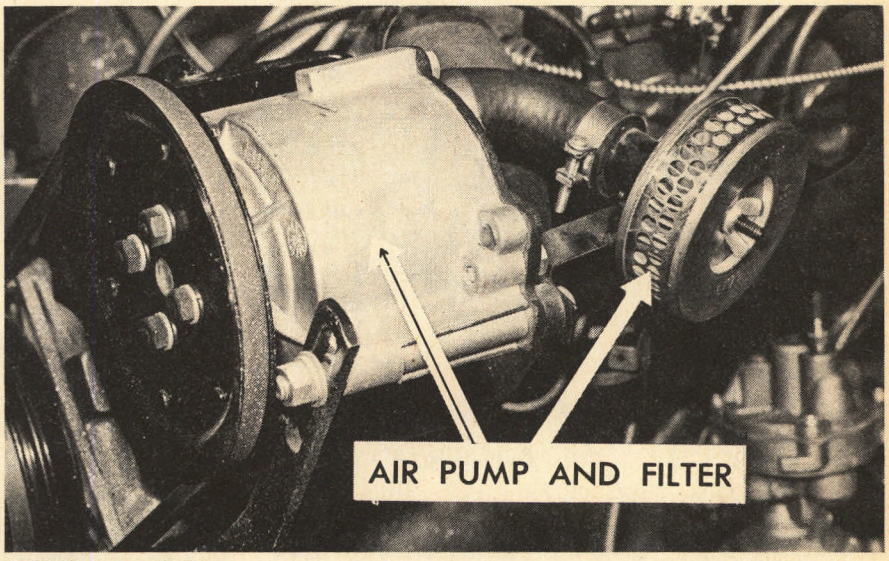
into the crankcase. From that point, blowby gases go through the hose into the PCV valve and into the manifold, just as in a Type 1 system.

When the Type 4 system is under zero vacuum, there's no suction on the crankcase (just as in Type 1), but the gases go from the rocker cover through the hose into the air cleaner, where they're drawn into the engine. If an engine has a lot of blowby, some of the gases will pass into the air cleaner at all times. The resulting oil fumes will ruin a dry paper element in a short time. The remedy here is to fix the engine so that it does not blowby as much, or change to an oil-wetted element.

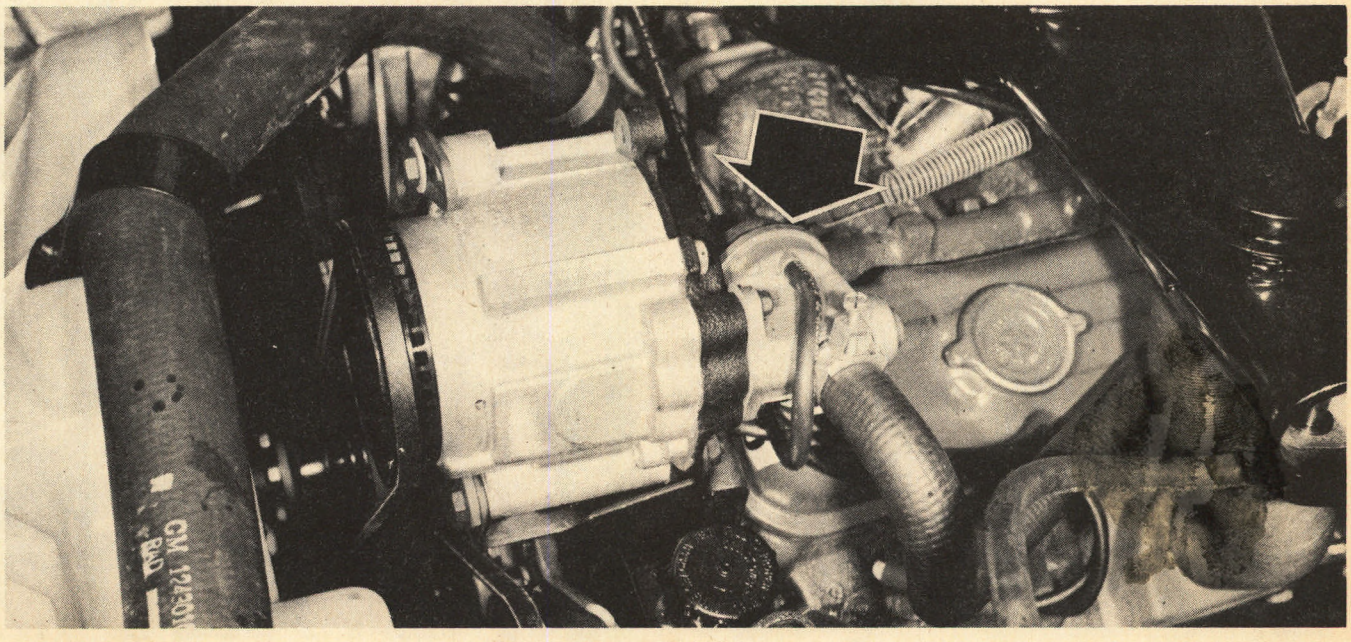
That's a brief rundown of the four types of crankcase devices, and as you see, they aren't really difficult to understand. It's amazing that something as simple could have caused as great an uproar as it did among car owners and mechanics alike when Type 1 devices were factory-installed on all new cars sold in California in 1961. Problems arose at that time because few people understood just how the things worked,



2. Anti-Backfire Valve



3. Air Pump and Filter



4. Diverter Valve

and there were some cases of poor design that aggravated matters. But the manufacturers cleared that up and so smog valves settled down to their job.

The uproar began all over again in 1963-64 when the new cars were equipped with a Type 4 system instead of Type 1, and devices were required by law on some used cars. The used car scene was really a bad one, as mechanics and car owners didn't always follow instructions when installing the devices. One source of trouble was the installation of a crankcase device on a worn-out engine. In such a case, the device could cause plug fouling, along with other complications. But the law simply stated that such a device *would* be put on a car, with no provision for the fact that once it was installed, the car might not run properly. The only solution with a worn engine is to junk the car, or to do a ring and valve job, which can often cost more than the car is worth.

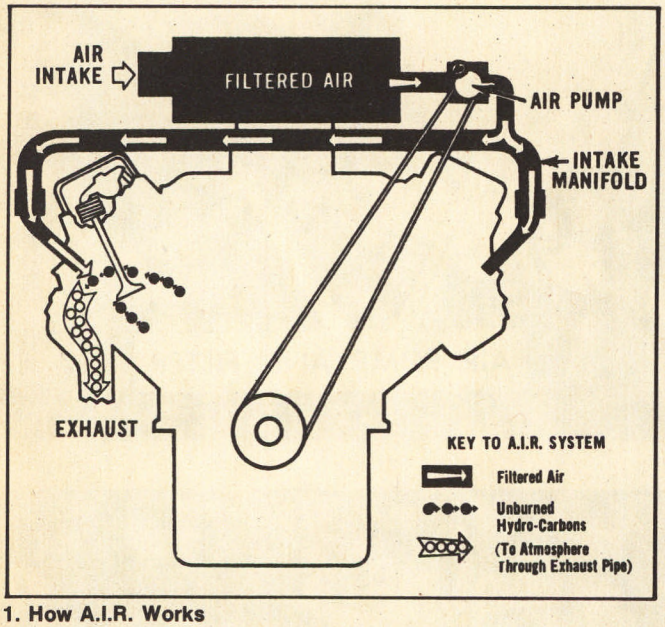
But in all fairness, we must point out that if an engine is worn so badly that it won't accept any crankcase devices, then it must really be in terrible condition. There's no such thing in California as an exemption for worn engines—the car must comply with the law or it can't be operated on public streets—it's that simple. This may seem unfair but there are many states where a cracked windshield, bald tires, or a brake pedal that goes down too far will result in our being unable to drive the car until it's fixed—and fixing those cars may also cost more than they're worth.

Occasionally, a smog device is installed and the car runs rough, or a smog valve is changed and the car won't idle without shaking you off the seat. This can be caused by installing the wrong valve or system for that particular engine. You just can't make up a smog device from tubing, hose, and a few other available parts. The entire device must be designed to fit and be approved for that particular engine by the proper authorities. It must also be installed exactly as instructed, with the tune-up performed according to specifications or the engine won't perform, smog device or no smog device.

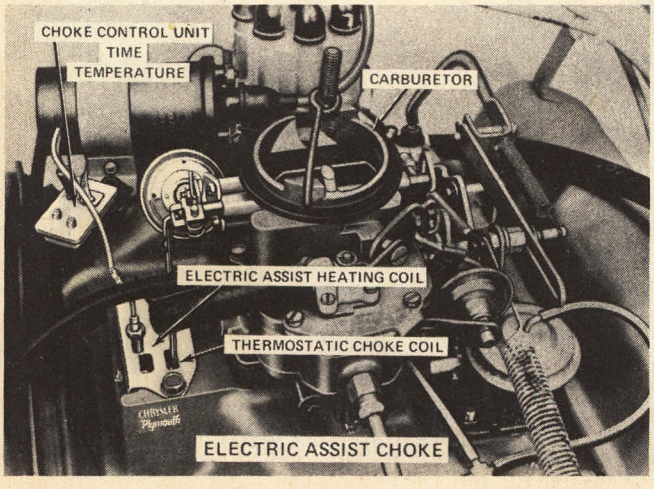
Do smog devices do any good? Well, they do a better job of crankcase ventilation than any road draft tube ever did, resulting in less oil contamination and a longer lasting engine. Crankcase systems do cause slightly increased intake valve and intake manifold deposits, but the increase is so slight that authorities claim it won't hurt an engine.

Maintenance of the crankcase device is important. If the valve or hoses are allowed to plug up, damage to the engine can result. Some car manufacturers say that the system should be checked at every oil change; others recommend cleaning or replacing the valve once a year or every 12,000 miles. Checking the valve is simple. It should be clean, and the plunger should be free so that it rattles. If it's the fixed-orifice type, the hole should be clear of all obstructions, as should any hoses. Any flashback screens in the hoses should also be clean. The Type 2 valve is never cleaned, but a simple test of mouth suction will tell you if it's OK.

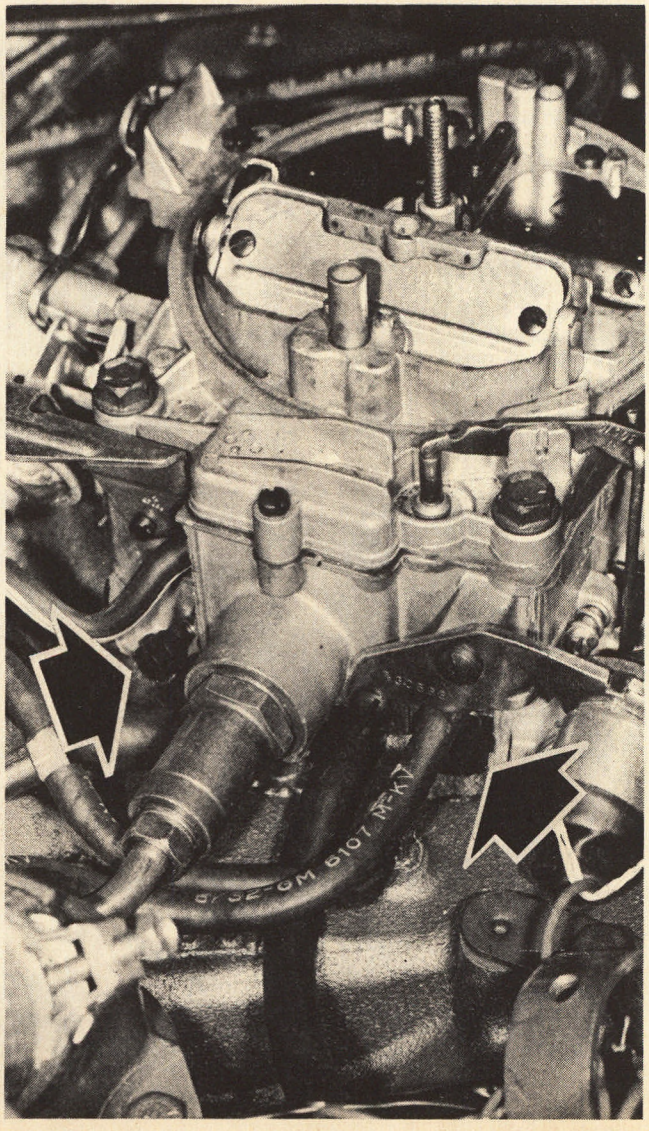
Different systems are found on different year models. While there are exceptions, you'll usually find the following: California models 1961-63½ have factory-installed Type 1 systems. California models 1963½ and later have factory-installed Type 4 systems. Prior to 1963, cars sold outside California had no



1. How A.I.R. Works



2. Chrysler Electric Assist Choke



3. Limiter Caps

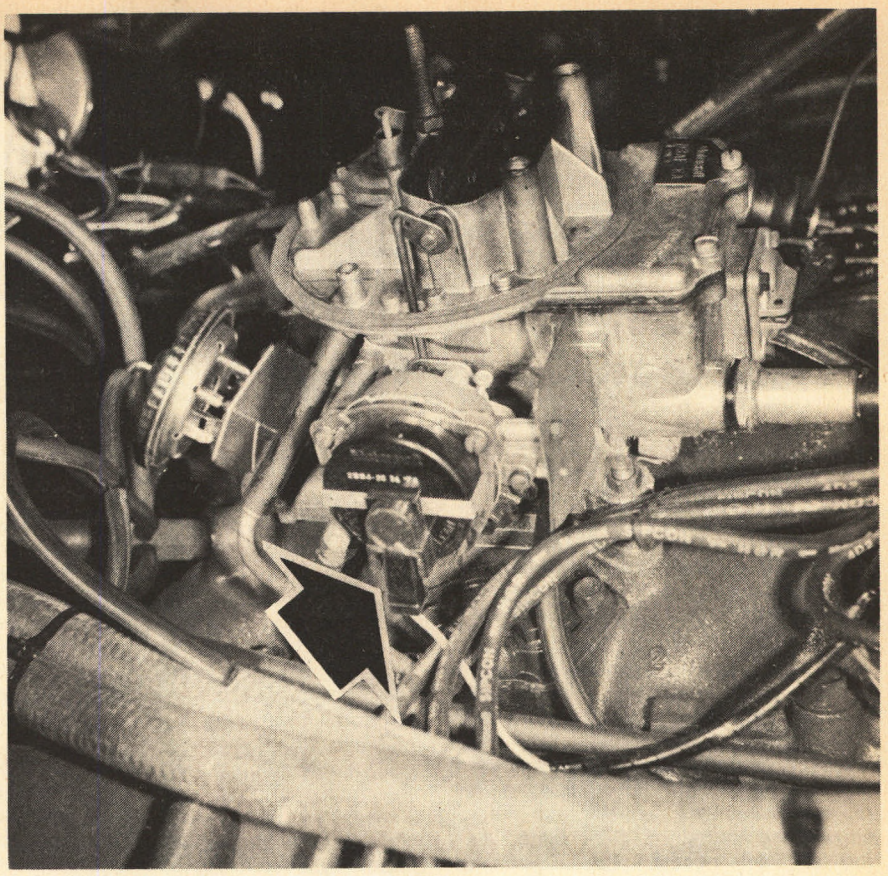
1. Unburned hydrocarbons enter the exhaust manifold and are burned near the valve when air from AIR pump hits them. Exhaust manifold or entire exhaust system can get much hotter than it would without pump.

2. Chrysler Corp. has equipped all its 1973 engines with an electric assist choke to reduce emission during starting and warm-up. Heater element is located in choke well and is completely covered with a nonconductive insulation. Time/temperature control unit operates heater.

3. Black limiter caps on carb idle mixture screws are one part of ignition-induction system. If original black caps have to be removed during carb overhaul or adjustment, they are replaced with red ones that indicate an alteration has been made.

4. Ford's electric choke heater is contained in the thermostatic choke spring and draws power by direct tap from alternator. A bimetallic disc acts as control switch.

5. Orifice Spark Advance Control (OSAC) is latest Chrysler Corp. device to delay vacuum advance during acceleration. Delay is accomplished by restricting airflow from distributor advance chamber to carb port. Special thermal cutoff device incorporated in the OSAC valve assures satisfactory driveability when outside temperature is below 58° F.



4. Ford Electric Choke

5. OSAC System

crankcase system; 1963-67 cars manufactured for sale outside California have Type 1 systems, and from 1968 on, the Type 4 system has been used nationwide.

If your car came with a crankcase device, than you must not remove it under penalty of California law, unless for the purpose of putting a used car device in its place. If your car did not come equipped with a device, there are certain situations that will require you to install one. It all depends upon the year and model of the car and where it's registered, in most cases. Models from 1955 to 1962 must have a crankcase device if their ownership is transferred to someone who lives in a county that requires it. This doesn't mean that the new owner can then remove the device once the car has been registered under his name. After installation of a crankcase device, you're breaking the law if you take it off.

Some exceptions have been provided in the law for certain types of engines, but these are gradually being closed. Motorcycles are also exempted. We won't go into all of the technical details pertaining to California law here, as the idea is only to give you general knowledge of the California situation and what you might expect in your own state. Now let's get into exhaust controls and find out how they work.

EXHAUST CONTROL SYSTEMS

If hydrocarbons are mostly unburned gasoline, then it follows that when the engine is putting out hydrocarbons, it's running with a rich mixture. If the engine could be made to run on a leaner mixture, it wouldn't cause nearly as much

pollution as it does with the richer one. The problem is to find out whether a particular engine is running rich or lean. This is done with the use of an exhaust gas analyzer, a test instrument manufactured by tune-up equipment makers. These analyzers have been around for many years now, but basically they all work the same—by measuring the thermal conductivity of the exhaust gas, which is directly related to how rich the engine is running.

The analyzer meter gives its reading in an air/fuel ratio, which may range anywhere from 11:1 up to 15:1. If the meter read 12.5:1, it would mean that the engine was running on a mixture with an air/fuel ratio of 12½ lbs. of air to 1 lb. of fuel. A rich mixture is one that contains an excess amount of fuel, and a lean mixture, of course, is just the reverse. Any reading near the 15:1 end of the scale is lean, and a reading on the 11:1 end of the scale is rich. An engine can run as rich as 8:1, but only if you're wealthy and the gas pumps are spaced close together. The leanest the analyzer will measure is 15:1.

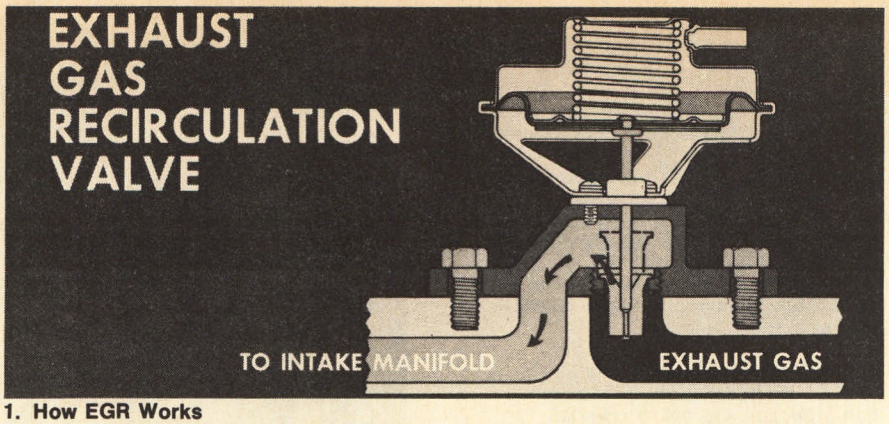
Most engines without exhaust emission controls run about 12:1 at idle and at cruising speed, they usually lean out to somewhere around 14:1. The richer mixture at idle is necessary because some exhaust gas remains in the combustion chamber at idle speed. Engines also run rich on deceleration, but under most other operating conditions, they'll run sufficiently lean to avoid overly polluting the air. So the problem really narrows down to an elimination of the rich mixture during idle and deceleration. There are two ways to do this within the confines of the present state-of-the-art—with either an air injection system or an ignition-induction system.

AIR INJECTION SYSTEM

Essentially, the air injection system is little more than an engine-driven pump that transfers air from outside the engine into the exhaust passage close to the exhaust valves. As the unburned fuel comes out of the exhaust valves, it combines with the fresh air provided by the pump and actually burns right in the exhaust passage. This means that the exhaust system gets considerably warmer than it would without the pump system, and it also means that there has to be a lot more "plumbing" to handle air movement cluttering up the engine compartment.

Authorities claim that a warmer exhaust system can be beneficial in that it may eliminate condensation in the muffler (the major cause of mufflers falling apart), but not enough statistics are in to make any really definitive statement about this yet. Even though air pumps have been used for several years, mufflers seem to fall to pieces just as rapidly, if not more so, than before. And mechanics who work primarily on the small 4-cylinder engines used in Pinto, Vega, and the import cars will tell you that those with air-injection systems tend to have a much shorter exhaust valve life.

That cluttered exhaust control mess in the engine compartment is something we have to live with, and since it seems to get worse every year, let's take a look at exactly how an air-injection system works. Mounted at the front of the engine, the air pump is driven off the front pulley by a belt. All pumps draw their air from the engine compartment, but different manufacturers have take different approaches; some pumps use a filter on their air intake and others receive the air from the clean side of the carburetor air cleaner.



1. How EGR Works

1. EGR valve acts as one-way switch routing exhaust gases to intake manifold except during idle/deceleration condition, when addition of gases to incoming air/fuel mixture would cause rough engine operation.

2. All 1973 cars use an EGR system. One arrangement is Chrysler's Proportional Exhaust Gas Recirculation, which incorporates an EGR valve and sophisticated vacuum sensing to assure proper flow of exhaust gases.

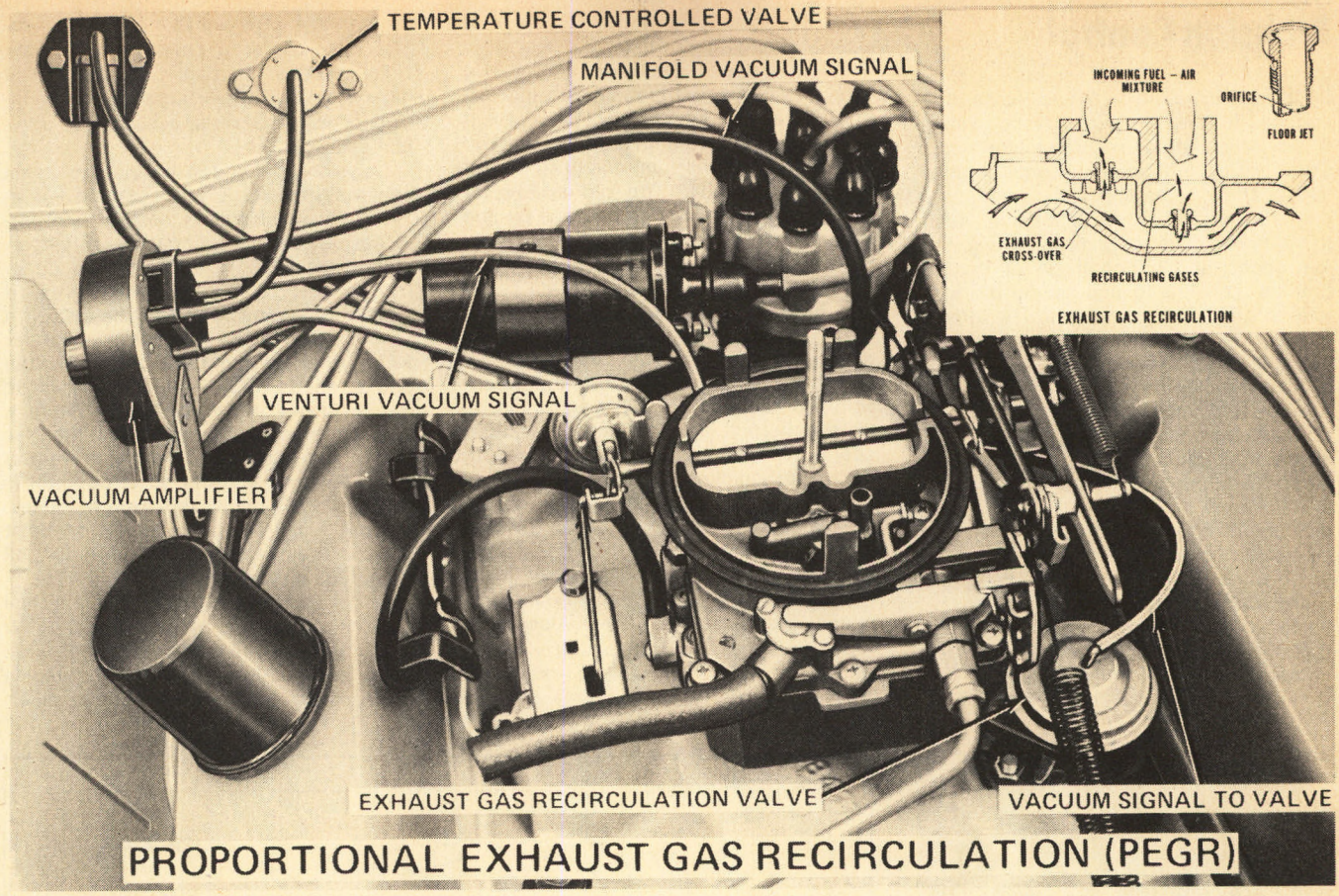
Various methods are used to move the air from the pump to the exhaust valve. The air travels (under pressure of about 1 psi) from the pump to a manifold on each cylinder head. Then it moves into the injection tubes that direct the air to the underside of each exhaust valve. Some engines like Buick use a passageway cast into the cylinder head instead of an external manifold. Chevrolet V-8's have the injection tubes entering the exhaust manifold and from there they go up the passageway to the exhaust valve.

All air-injection systems have check valves with a one-way diaphragm to prevent the hot exhaust gas from backing up in the system to the pump in case of high exhaust-system pressure, pump belt failure, or air hose rupture. All late models use a diverter valve that prevents excessive pressure in the system from causing a backfire. It does this by sensing sudden increases in intake manifold vacuum, causing the valve to open and let air from the pump vent outside. A pressure relief valve is contained in the same housing. Early models used a bypass valve which performed the same function as a diverter valve. Pump relief was provided by a second valve in the air pump itself.

The diverter or anti-backfire valve works by sending the air output from the pump directly into the intake manifold instead of into the injector tubes. This leans out the excessively rich mixture that occurs just after you lift your foot from the gas. If this mixture were not leaned out, it would explode in the exhaust system, causing a loud noise from the tailpipe. Some anti-backfire valves dump atmospheric air into the intake manifold instead of pump air. Other types don't dump air into the manifold but allow the pump air to exhaust into the carburetor air cleaner instead. This effectively cancels any airflow through the injector tubes, and silences the sound of the exhausting air. Design of the backfire valve depends upon who's sitting at the drawing board and what he feels is necessary to stop the engine from backfiring.

The backfire valve only operates to eliminate backfire just after the driver removes his foot from the pedal; after that, the air-injection system returns to normal operation whether you put your foot back on the gas or leave it off. These diverter valves can cause some strange things to happen when the car is started. Since the valve is controlled by engine vacuum, it takes a couple of seconds for the vacuum to build up. Until it does, the type of valve that dumps air into the manifold is wide open, allowing outside air to enter. Some engines may shake like jello until the vacuum builds up sufficiently to close the valve. This doesn't really do any harm to the engine or anything else, but it sure makes the unknowing driver wonder just what's going on under the hood and it's likely to send the little woman to the nearest searvice station in tears.

If the air injection system consisted of just the pump and its corresponding plumbing, things would be fine. But it also requires changes in the carburetor, distributor, cooling system, and many internal changes in the engine proper. This means that it's impossible to use the air-injection system from one engine on another. It might be possible to design a universal system, but the cost would be fantastically high and would probably involve changing everything on the engine except the crank, block, and rods. And who could get the Big Three to cooperate on such a project? Like all other smog controls installed to date, the air-injection system is really an emergency system hung on the car's engine because nothing else that would drop the emissions to the level specified by the politicians was available. Air injection will be around for a long time yet, for despite those who placed their money on the ignition-induction system as an alter-



2. Chrysler EGR System

native, manufacturers are discovering that with many engines, meeting the 1975 specifications requires a combination of the two.

IGNITION-INDUCTION SYSTEM

The ignition-induction system was pioneered by Chrysler Corporation, who installed its Clean Air Package (CAP) on 2000 of the 1963 Plymouths. As these cars were sold only to fleet accounts in the Los Angeles area, a careful check on how they performed was feasible and led to approval of the CAP system in November 1964. This exhaust emission system worked so well that similar systems have now been adopted by the competition (sometimes from sheer desperation) and ignition-induction is used on many new cars.

Sometimes called an "engine modification system," ignition-induction reduces emissions at idle by using a carburetor that's set lean. On some cars, the idle mixture screws are installed with a pin in the throttle body to prevent anyone from backing them out to obtain a richer mixture. If the screws are backed out with force, they break, and the carburetor must be removed from the engine. The pins and screws are then replaced with parts from a special kit. Other cars use idle mixture screws with limiter caps that butt against the carburetor to prevent the screws from being turned beyond a certain point. Still, other carburetors don't use limiters because their idle mixture needles were designed so that the mixture cannot richen excessively, even if the screws are backed out.

If a lean mixture is all that's required to reduce emissions, it then follows that adjusting the carburetor on the lean side will do the trick, or will it? The only problem here is that the engine won't run. Exhaust dilution of the mixture at idle requires an air/fuel ratio of about 12:1. The mixture is also very thin because it's under a high vacuum. Both problems can be overcome by opening the throttle wide enough to get a denser mixture and more flow to scavenge some of the exhaust gases from the cylinder so that the engine will run at 14:1. The result is fewer emissions, but the engine is idling so rapidly you can't hold it down. Without touching the idle mixture or mixture adjustment, retarding the spark is the only other way to get engine speed down to a normal idle.

And that's just what Chrysler did; all CAP engines have an initial spark setting that's retarded as much as 15° from normal; this is accomplished by a ported spark. When the throttle is closed, the spark port is above the throttle plate. Since there's no vacuum on the advance diaphragm, the distributor goes into full retard. But when the throttle plate is opened, the spark port is uncovered and the vacuum diaphragm advances the spark up to a conventional setting.

With this system, the spark is retarded during deceleration, because the throttle plate is closed at that time. The designers discovered that the only way to reduce emissions during deceleration was to advance the spark. This is done by placing a little spark valve in the line between the carburetor and the vacuum advance diaphragm and connected to manifold vacuum. Whenever you lift your foot, this spark valve sends full manifold vacuum to the distributor advance diaphragm, which then advances the spark. The spark valve will hold the distributor in full advance position as long as the deceleration continues, even if the car is going downhill from here to you know where. But as soon as manifold vacuum drops below about 21 ins. (the figure is lower on '72-'73 models), the spark valve changes the distributor back to carburetor vacuum and the distributor works normally again.

The CAP system has been modified by other manufacturers so that it works a bit differently, but does the same thing. Some designs do not use the spark valve because their carburetors do not go rich during deceleration; others use the spark valve but their purpose is to eliminate exhaust popping, not to lower unacceptable emissions. The Chrysler distributor has one vacuum diaphragm to advance the spark all the way from retard position to full advance. Some Ford engines use a dual diaphragm with two hose connections, while Pontiac uses a single diaphragm with two hose connections. One hose goes to carburetor vacuum and the other to manifold vacuum. The carburetor vacuum hose controls the distributor in the normal way, but the manifold vacuum hose pulls the breaker plate to the retard position during idle and deceleration.

Actually, this is exactly opposite to the CAP system, which goes to full advance during deceleration. Ford and Pontiac were able to get away with this on some of their engines because of changes in combustion chambers, cam timing, stroke length, and other internal modifications. But it didn't work on all engines

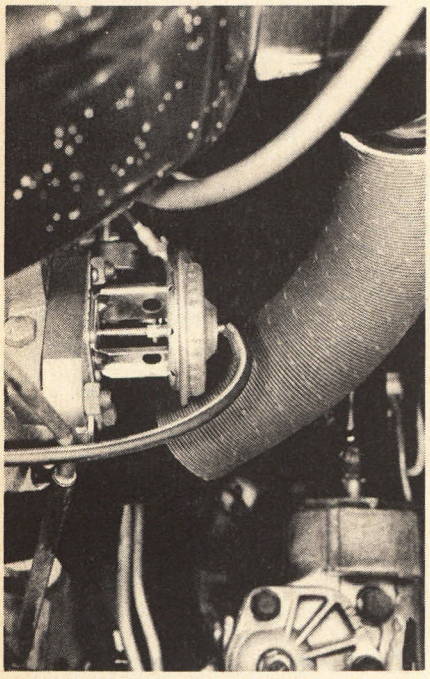
in their lines, so you'll find some that continue to use the spark advance valve. A similar situation exists on late-model Chrysler Corporation cars. Some engines use a spark advance valve and some don't. As you can see, there's no such thing these days as simply setting the idle speed and letting it go at that; a tune-up man has to understand the system he's working on and how it affects the engine. And he must be sure that he has the exact specifications for the engine he's tuning.

Some late-model Chrysler product carburetors have an idle-speed adjustment screw that seats against a little metal contact on their side, with a wire running to a solenoid mounted on the side of the distributor. When the throttle is in the curb-idle position, the idle-speed screw touches the contact, retarding the spark. If the carburetor also happens to be equipped with an anti-dieseling solenoid, then the contact for the screw is located at the end of the solenoid plunger.

What the solenoid retard does is to bring the spark to a retarded position to slow the engine down for an idle at a reasonable speed. The solenoid is just a small electromagnet mounted on the distributor vacuum advance chamber. It exerts a small amount of pull on the rod that links the vacuum diaphragm with the breaker plate. The old system of ported spark and a long throw on the single vacuum diaphragm worked very well for Chrysler, but the distributor solenoid modulator (DSM) did an even better job, because it allows advanced timing during a cold start. When cold-starting an engine, the fast idle cam holds the idle-speed screw away from the retard solenoid contact. A cold engine needs all the help it can get and the slight spark advance (about 5.5°) comes in handy for quicker starting. As soon as the engine warms up, the choke opens, the fast-idle cam goes off, and then whenever the throttle is let down to the idle position, the solenoid is energized and retards the spark to keep the idle speed at a reasonable level. Along with other changes, this system was modified on 1972 models to receive its power from the starter relay. Thus, the distributor solenoid now works only during engine cranking, and advances the spark 7.5° for better starting. Simplification of the system was made possible by the introduction of Chrysler's electronic ignition system.

Chrysler also added an electric assist choke system to its entire engine line in 1973. This system was designed to provide a quicker choke opening at temperatures above 63° F and a slower opening below 63° F. Ford uses a temperature-sensitive bimetallic disc as a switch to control the ceramic heater within the thermostatic spring of the choke on its 4300 4-bbl. This electric choke draws power constantly from a center tap on the alternator, but the disc switch remains open and no current is supplied until underhood temperatures reach 60° F, when the switch closes. Current supplied to the ceramic heater causes the thermostatic spring to pull the choke plates open within 1.5 mins.

Chrysler's original CAP system has now been changed to CAS (Cleaner Air System). The changes involved were many and subtle ones inside the engine where they made a considerable differ-

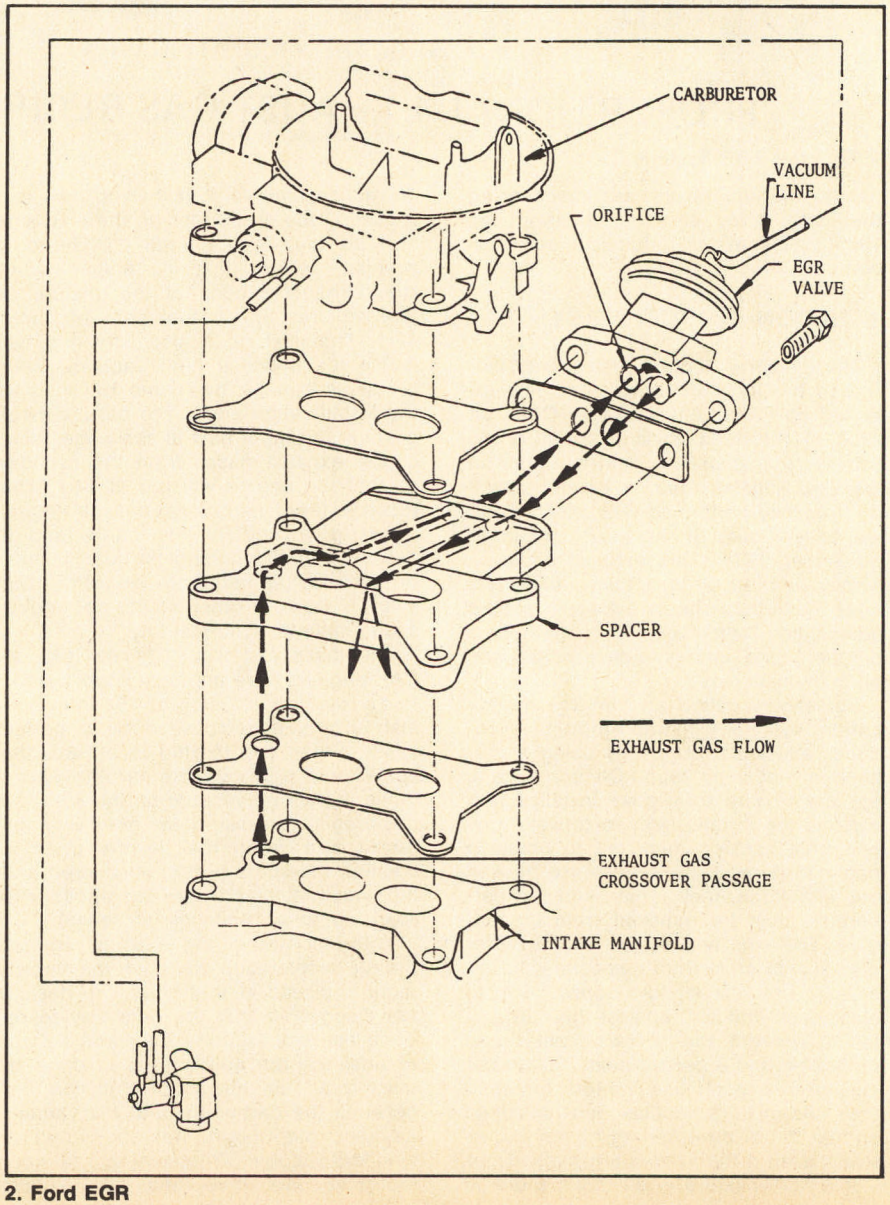


1. Chrysler EGR Valve

1. EGR valve location differs from engine to engine. Valve is not repairable and must be replaced if not working properly. Dodge 198- and 225-cu.-in. engines have unit mounted on intake manifold, where value stem action is easily visible.

2. Ford's EGR system is considerably more complex than that of other manufacturers. An internally-channeled spacer unit fits between intake manifold and carb, and has valve mounted at its back. Depending upon engine, the valve may be a poppet, modulating, or tapered-stem type.

3. Pinto equipped with 2000cc engine and manual transmission uses a Decel valve for 1973. Mounted on intake manifold, the valve meters extra fuel/air during deceleration to permit more complete combustion.



2. Ford EGR

ence in emissions, but very little change in servicing. Some strange things were done with the controls on some of the carburetors. There are 4-bbls. with single idle-mixture screws similar to some old Holley designs. Some carburetors have a bypass airflow (nonadjustable) that directs air below the throttle valve to break up raw fuel. But even with its advanced thinking behind CAP and CAS, Chrysler found it necessary to resort to an air pump system in addition to the ignition-induction system in order to make certain engines in its line conform to standards for 1973.

A temperature-sensitive, vacuum control valve is used on many cars. This screws into the water jacket and is connected between the distributor, carburetor, and the intake manifold. The source for the distributor vacuum-advance unit is the port above the throttle plate, resulting in no spark advance at idle. As the retarded spark at idle may cause an engine to overheat in heavy traffic, the control valve senses excessive heat and changes vacuum source from the spark port in the carburetor to full intake manifold vacuum, causing the spark to advance and speeding up the engine to help overcome the heating condition. This thermo switch is not really much different from the old air-conditioning idle speed-up solenoid used on many early air-conditioned engines.

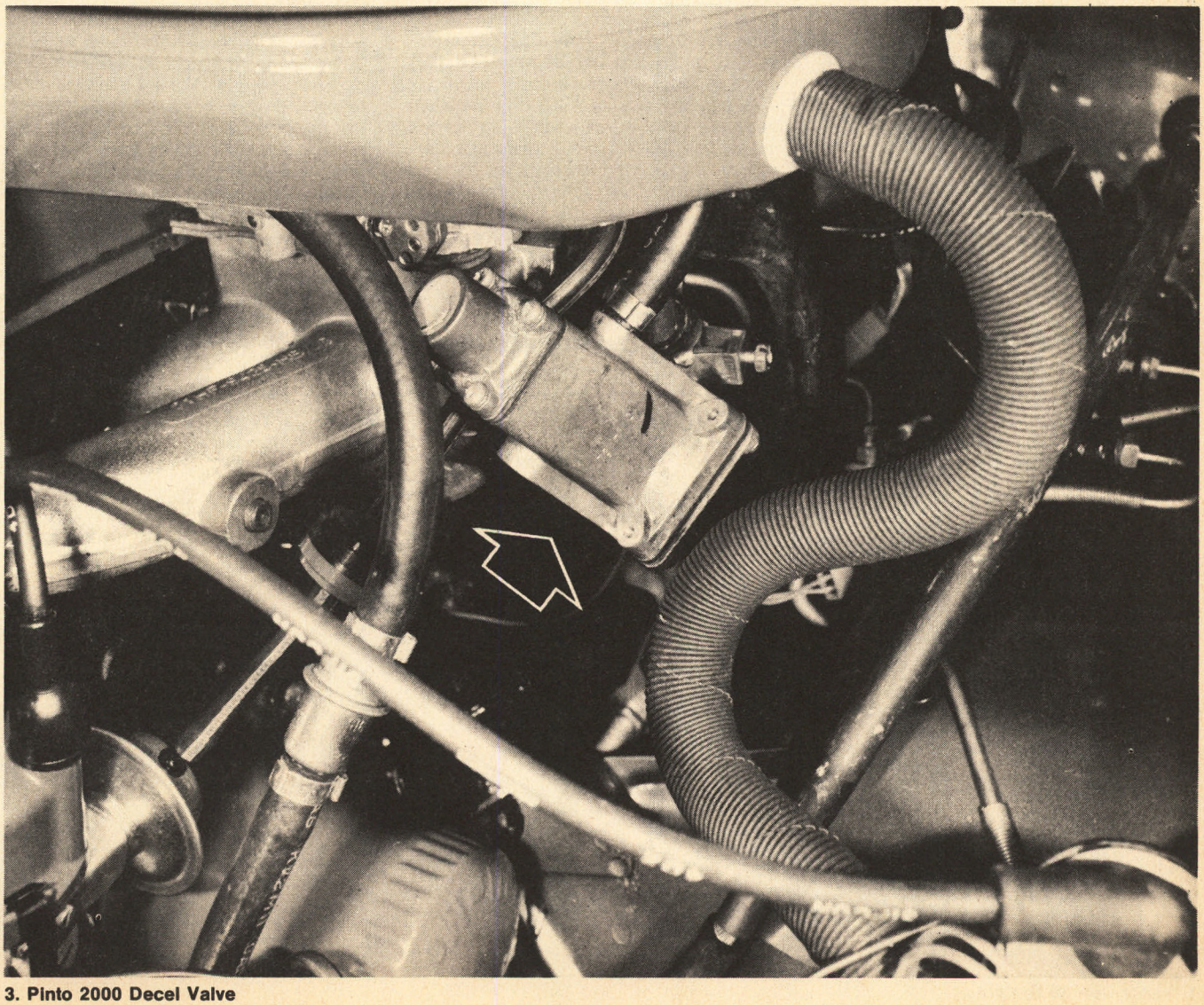
But if you think that Chrysler Corporation's solenoid retard is complicated, take a look at Ford's Electronic Spark Control (ESC) system. A speed sensor hooks into the speedometer cable to control the spark advance according to the car's speed. There's no spark advance at all until the engine reaches about 23 mph on acceleration, when spark advance works normally. On deceleration, the distributor modulator valve shuts off the vacuum to the advance unit as the vehicle speed drops to approximately 18 mph, and the spark is allowed to retard. The electronic module works in conjunction with the usual dual-diaphragm Ford vacuum-advance unit. The diaphragm closest to the distributor is for retard and is connected to manifold vacuum; the other connects to the spark port on the carburetor above the throttle plate. This ESC system is entirely separate from the electronic rpm limiter appearing on some Ford products; the two units have no connection and could be used on the same engine if Ford wanted to install them that way.

GM and Chrysler also have spark control systems. The GM system is called Transmission Controlled Spark (TCS). A switch in the transmission connects to a solenoid that controls the vacuum applied to the distributor diaphragm, resulting in the elimination of vacuum spark advance in all lower gears. On a 4-speed box, you'll get vacuum spark advance in 3rd and 4th gears, but only in top gear with all other transmissions.

COMBINATION EMISSION CONTROL VALVE

Chevrolet eliminated the TCS solenoid in 1971 in favor of a vacuum-electric gadget called a Combination Emission Control (CEC) valve. This looks very much like an anti-dieseling solenoid, but it doesn't do the same job. Unfortunately, it occupies the same space on the carburetor, so many mechanics have probably used the CEC valve plunger to set curb idle. Just for the record, never use a CEC valve plunger to set the curb idle; the normal throttle-cracking screw on the carburetor is the proper route to go.

CEC does exactly the same thing with vacuum spark-advance as a TCS system, but an additional function opens the throttle on deceleration. If the throttle is allowed to close to the curb idle position



3. Pinto 2000 Decel Valve

during deceleration, a high vacuum results and pulls in huge amounts of raw fuel through the carburetor idle system. But keeping the throttle at a slightly greater opening reduces the vacuum, creating fewer emissions because the mixture is not as rich.

CEC does both tasks at the same time, so that whenever there's vacuum spark elimination, you also have a greater throttle opening on deceleration. The CEC valve can do both at once as it has a long plunger, one end of which shuts off vacuum to the distributor while the other end moves away from the throttle linkage. When the transmission shifts into top gear, electricity flows to the solenoid coil in the CEC valve, moving the plunger out. This movement uncovers a hole to allow vacuum to the distributor and at the same time, the end of the plunger moves out to prevent the throttle from closing completely.

Additional controls complicate the CEC valve. A temperature switch cancels the whole operation to allow vacuum advance below 82° F. A time-delay relay cancels the CEC valve for 15 secs. after turning on the ignition switch to provide vacuum advance for easier drive-away and fewer stalling-after-start problems. Curb idle on CEC valve carburetors is set with the throttle-cracking screw, as we said earlier. Deceleration idle setting (considerably higher) is set with the CEC valve plunger in the energized position. If curb idle is set with the CEC valve plunger, the throttle will be held open too far on deceleration, giving you quite a surprise when you take your foot off the gas and the car keeps right on going. The vacuum hose connection on the CEC valve differentiates it from the ordinary anti-dieseling solenoid, which has no hose.

Because the throttle is automatically held open on deceleration, it isn't necessary to idle the '71-'73 cars as fast as in the past, and so idle specs have dropped 50-100 rpm, making anti-dieseling solenoids unnecessary in many cases. As air-conditioning demands faster idling, which leads to dieseling, a solid-state time device on air-conditioned Chevrolets holds the compressor on for 3 secs. after the engine is turned off. This extra load slows the engine down and keeps it from dieseling.

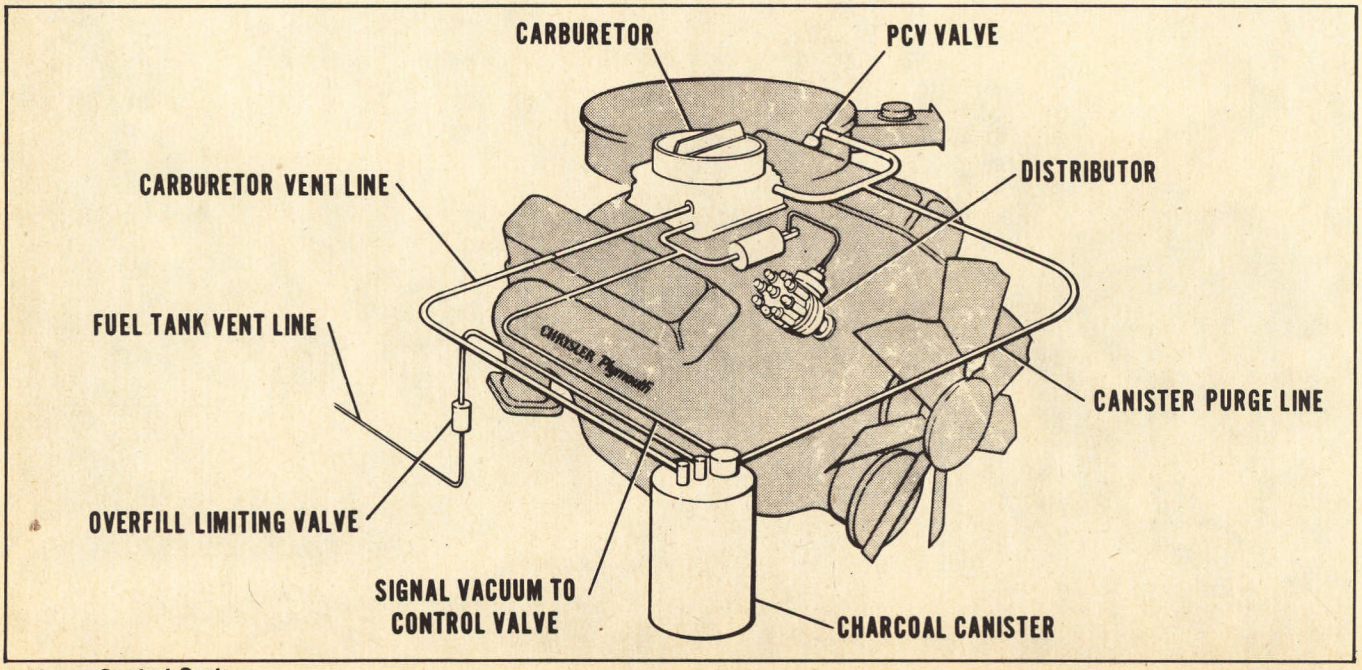
NOx SYSTEM

Installed on all California cars in 1971 (and nationally in 1972), Chrysler's Nitrogen Oxide (NOx) system takes the place of the previously mentioned solenoid-controlled spark advance. In case you haven't heard about NOx, it's the stuff that makes your eyes smart so badly on a smoggy day in L.A. As initial efforts toward emission control concentrated on hydrocarbons, little attention was paid to NOx emissions, resulting in a lessening of hydrocarbons but an increase in NOx in L.A. Chrysler's approach to NOx control was rather sophisticated, using a special camshaft with increased overlap. This overlap produces more exhaust gas contamination in the cylinder, which reduces peak combustion chamber temperatures, the primary cause of NOx emission. Along with a camshaft, the engines are equipped with a 185±thermostat, a move directly opposite to that made to reduce hydrocarbons, which resulted in the use of 195± thermostats. Because of the many other changes made, this doesn't mean that hydrocarbon emissions will increase, but you can see a rather complicated interplay of forces at work here. The lean mixtures necessary to bring hydrocarbons under control resulted in higher combustion chamber temperatures, and so an increase in NOx emission.

Until the 1973 model year, the heart of Chrysler's NOx system was a solenoid vacuum valve that controlled vacuum spark advance. On manual transmission cars, this valve is connected to a transmission switch to eliminate vacuum advance in all but top gear. In any other gear position, the valve is energized, shutting off vacuum to the distributor. In high gear, the transmission switch breaks the electrical circuit to the solenoid, the spring in the valve opens the passageway, and vacuum is allowed to advance the spark. The only additional control on manual transmission cars is a thermal switch mounted on the firewall to sense the temperature in the fresh air cowl inlet. Below 70±° F, the thermal switch breaks the circuit to the solenoid valve which allows normal vacuum spark advance; above that temperature, the thermal switch makes the connection and allows the NOx system to operate as described above.

Automatic transmission cars are different—they have an increased-overlap cam, a 185° F thermostat, and solenoid vacuum valve, but the control mode is different. A control module, vacuum switch, thermal switch, and speed switch all work together to tell the solenoid when to turn distributor vacuum on or off.

Chrysler NOx control on the '73 line is handled by a temperature actuated Orifice Spark Advance Control (OSAC) and Exhaust Gas Recirculation (EGR) system instead of the solenoid vacuum valve. When going from idle to partial throttle, a small opening in the OSAC valve delays the change in ported vacuum to the distributor by about 17 secs., but when reversing the sequence (part throttle to idle), the change is instantaneous. As vacuum is provided by a tap just above the carburetor throttle plates, manifold vacuum is not present under idle conditions, but as soon as the throttle plates open slightly, the system kicks into operation, provided the temperature is 58° F or higher. EGR (see Exhaust Systems) is handled on Chrysler Corporation cars by



1. Vapor Control System

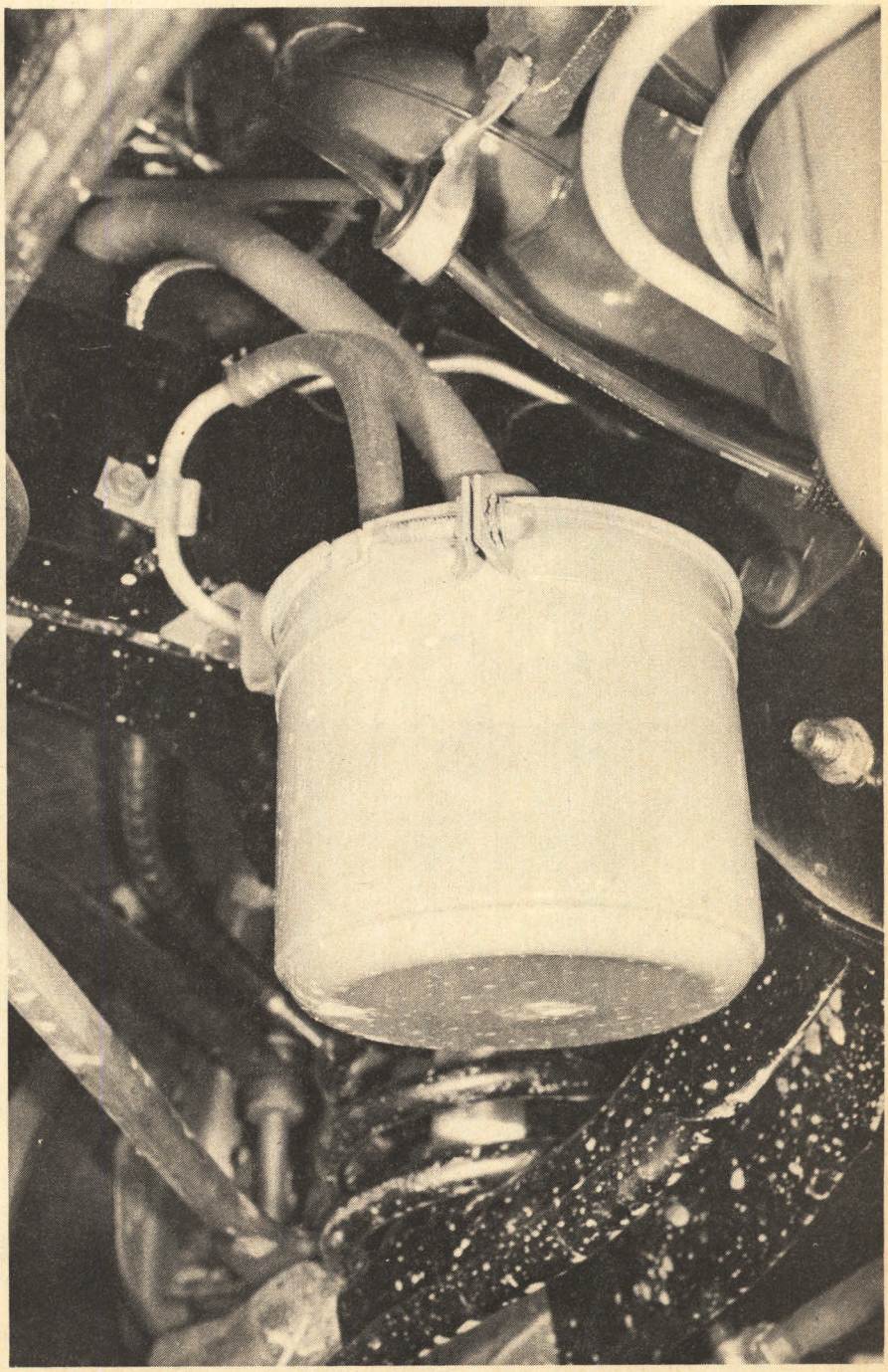
either a ported vacuum control, a venturi vacuum control, or a floor jet system, depending upon the engine involved, but the end result is the same—a predetermined amount of hot exhaust gases are recirculated to dilute the incoming air/fuel mixture and to lower the combustion temperature, thus reducing NOx emissions.

Ford's approach to EGR is tied into the engine coolant temperature as the actuating device, instead of the air temperature as used on GM and Chrysler cars. While the end result is the same as these other systems, Ford's is rather complicated in that the coolant temperature can be 60°, 95° or 125° F, depending upon the engine application involved. Ford also uses three different types of EGR valves; a poppet, a modulating, and a tapered-stem, again depending upon application. The temperature control device that activates the Ford EGR system is a vacuum switch similar to the distributor vacuum control valve used in 1972. To eliminate the add-on piping system used in other EGR designs, exhaust gases are picked up from the exhaust crossover passage in the intake manifold and routed through a thick carburetor spacer to the EGR valve which meters the gases back through another passage in the spacer. This means that the exhaust gases are directed to the primary bores where they dilute with the incoming air/fuel mixture headed for the combustion chambers. As vacuum for EGR operation comes from the carburetor's primary bore in this system, you'll find two vacuum ports on the carburetor, one for EGR control and one for the distributor spark advance.

Ongoing production changes have modified some Ford carburetors to use a single port for both applications. A more complicated version of this system was necessary to produce acceptable engine operation at high-speed cruise conditions. This high-speed modulator subsystem is used on the 351-C, 400, 429 and 460-cu.-in. engines and is similar in concept, components, and operation to the ESC system—Henry wouldn't recognize his infernal combustion machine if he could see how complex it's all become these days.

Beginning in 1970 with California cars and in 1971 nationwide, an additional system entirely separate from the exhaust and crankcase emission controls was added by manufacturers to reroute any gasoline vapors that might escape from either the fuel tank or carburetor. Except for a line going to the engine crankcase, the fuel tank is completely sealed. Vapors move along the line and are stored in the crankcase until the engine is started; then they are sucked into the intake manifold and burned. To keep liquid fuel from getting up to the crankcase, a vapor separator on top of the gas tank sends all the liquid fuel back to the tank where it belongs. Some vapor control systems use a canister filled with activated carbon to trap the vapors instead of letting them enter the crankcase. The carburetor float bowl also connects to the crankcase or the carbon canister (whichever is used), so that vapor from the float bowl will not escape into the atmosphere.

And where do we go from here? Well, it's another big leap in the coming months to meet the 1975 emission standards, unless the government relents and allows the manufacturers the extra year they insist is necessary. In the meantime, critics wonder why Detroit has not embraced the rotary engine, and legislators are turning their attention to the millions of used cars on the road that met standards when they were new, but are far from the 1975 levels. Some states like California are passing legislation requiring that additional devices be placed on used cars. One thing is certain, however. You can only expect emission control systems to get more complicated while exacting a heavy toll on performance and gasoline mileage. And if government agencies ever decide to put teeth into the legislation and establish a uniform system of enforcement, the do-it-yourselfer is virtually out of business. In the meantime, we're sitting right on the horns of a gigantic dilemma—will we as a nation pay the price for clean air, or are we content to look the other way and pretend that the polluted air doesn't exist? Only time will tell.

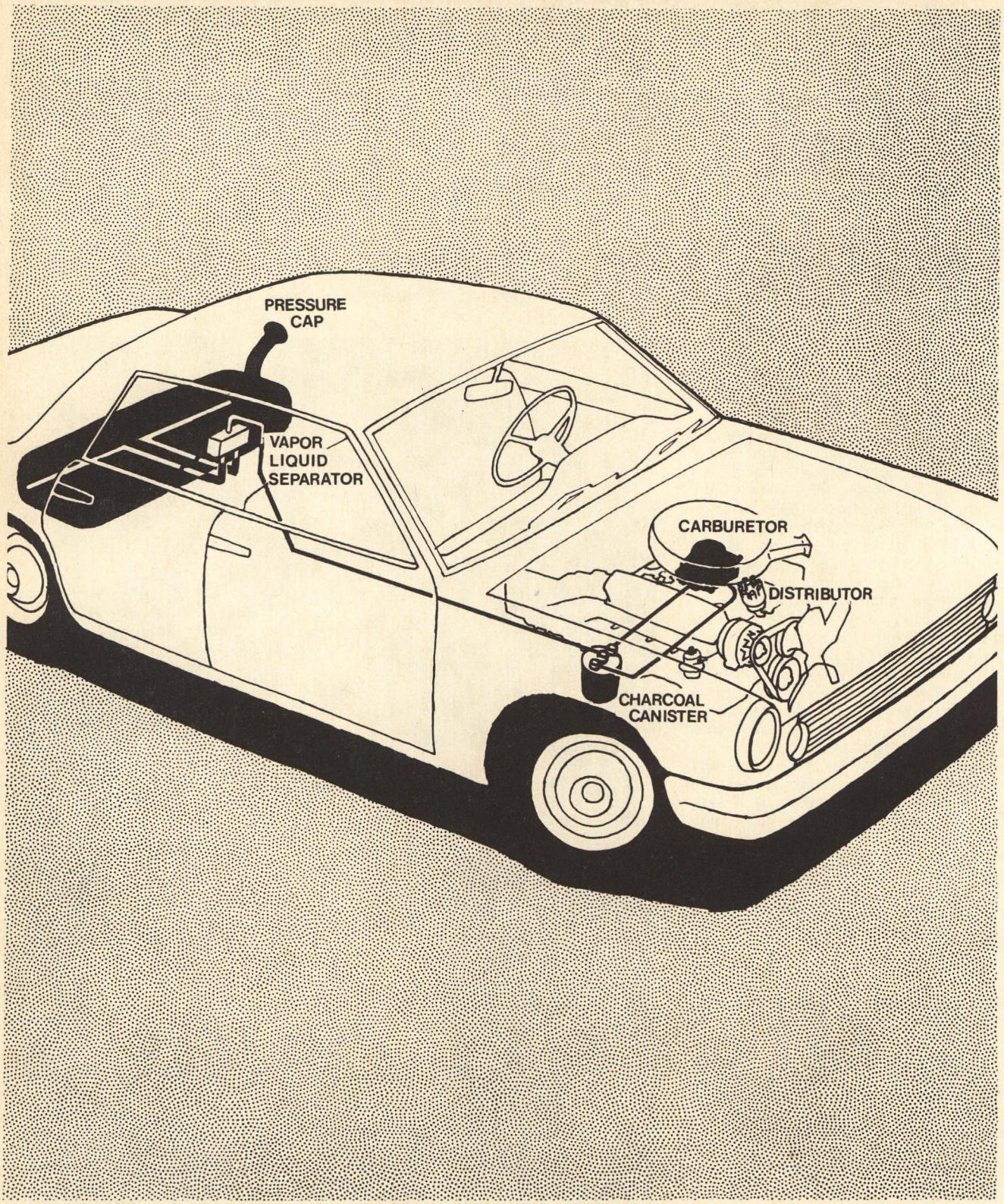


1. Late-model vapor control systems use a charcoal canister that traps fuel vapor which would otherwise escape from fuel tank or carb bowl. A vacuum-operated valve on top of canister channels vapor flow to engine.

2. FoMoCo uses a fuel vapor return system with certain engines to reduce amount of vapor entering carb. On 1973 Gran Torino, it's hard to get at unless car is on hoist.

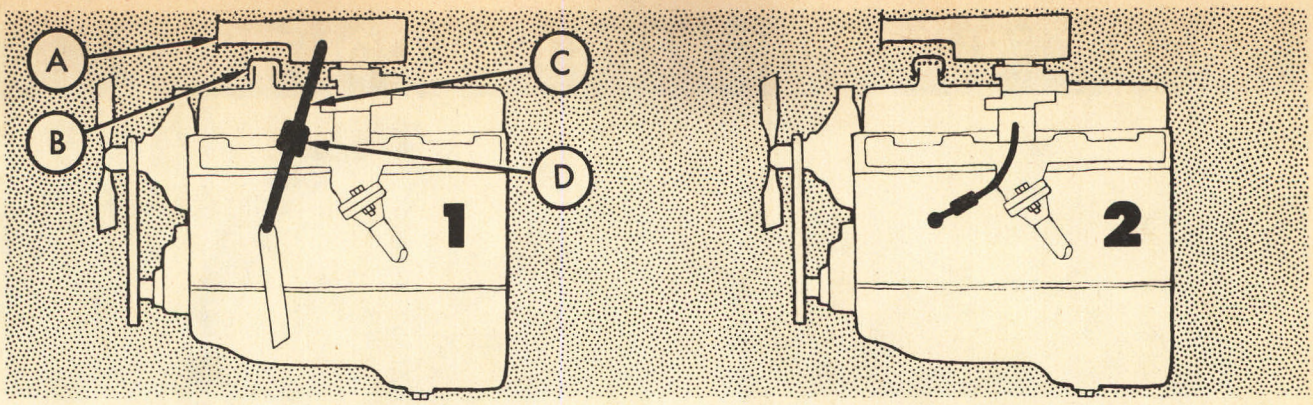
2. Ford Canister

TROUBLESHOOTING EMISSION CONTROLS

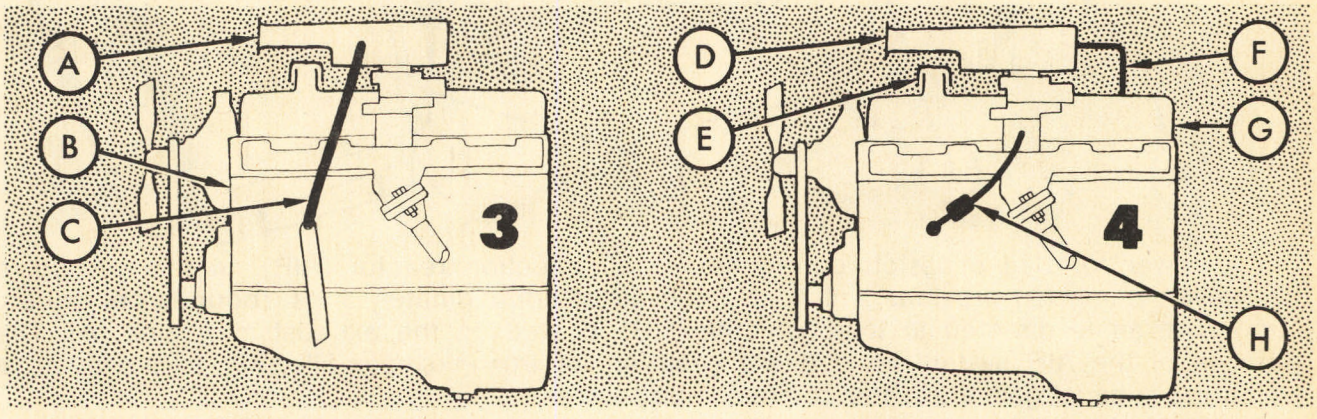


Emission control systems or smog controls are subject to certain problems, like all other engine components. There are several basic systems, but each manufacturer approaches the solution to pollution problems in a slightly different way, so each different brand of car may have emission control equipment that looks totally unlike that found on an automobile of another manufacturer.

Another problem that the troubleshooter should be aware of is that in many instances, the equipment is factory-adjusted. Attempts to work on the emission control system may be a violation of state or federal laws.



The simplest emission control system is the positive crankcase ventilation system (PCV). Before emission controls came into being, blowby fumes in the crankcase were vented to the outside atmosphere through a road breather tube. Since a large part of these fumes are unburned hydrocarbons (incompletely burned gasoline), this tube was a major source of smog. The PCV equipment stops this by routing fumes from the crankcase through a hose (C) which is equipped with a one-way valve (D) to the air cleaner (A). The oil filler cap (B) is vented to let outside air in. When the engine is running, fumes are extracted from the crankcase by engine vacuum. They are sucked into the hose, through the one-way valve and into the carburetor. They then enter the cylinders, where they are burned along with the air/fuel mixture. This system is known as the Type 1 PCV system. The Type 2 PCV system is the same except that the oil filler cap is designed to limit the intake of air to the crankcase. The valve in the Type 2 system is a diaphragm type that regulates the amount of flow according to crankcase vacuum. The Type 2 system valve keeps the crankcase at a mild vacuum to make sure all fumes are extracted under all running conditions.

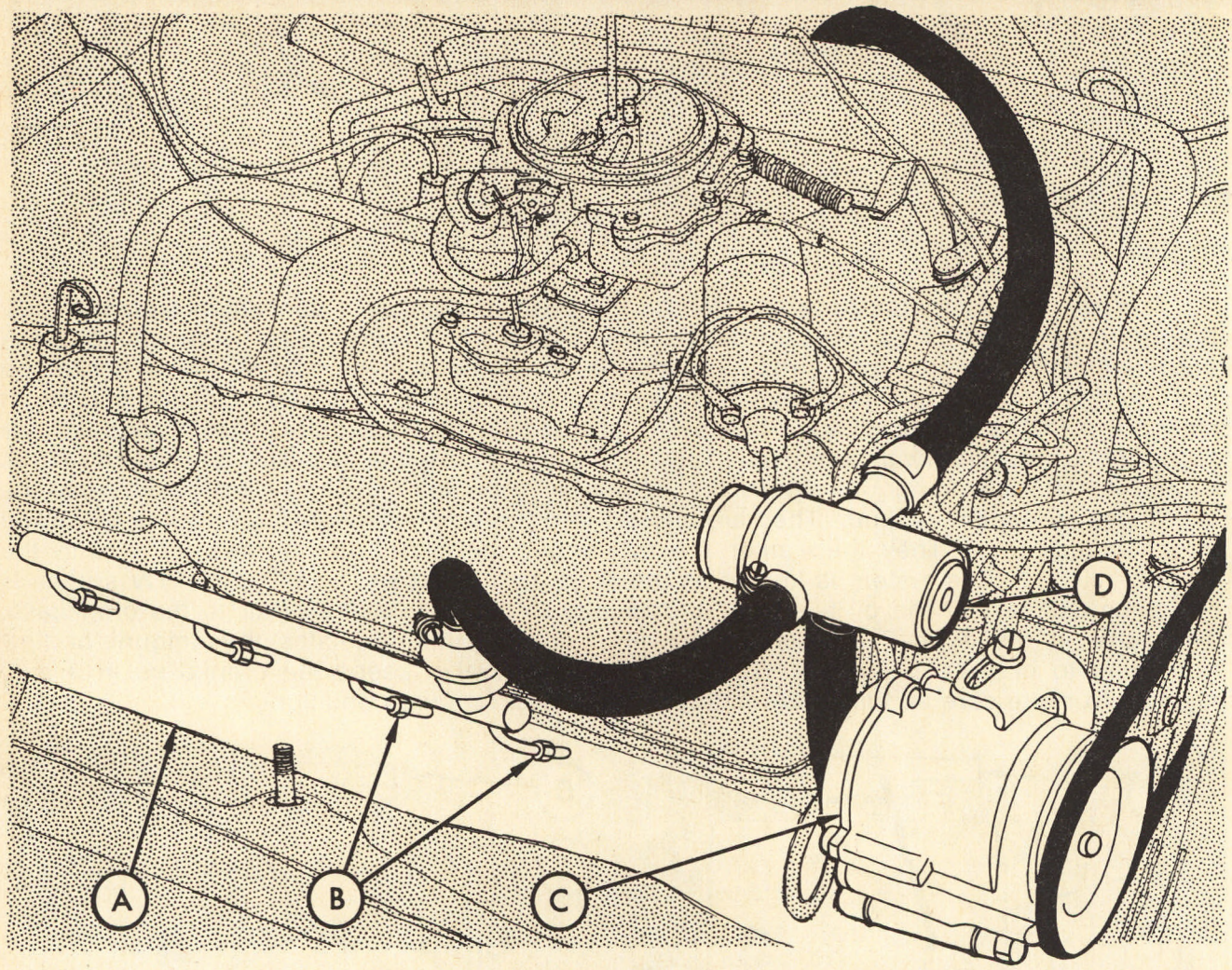


The Type 3 system is simpler in that it has no valve, simply a hose (C) running from the crankcase (B) to the air cleaner (A). The latest type, Type 4, is a combination of Types 1 and 3. A sealed oil filler cap (E) prevents fumes from escaping under zero vacuum conditions (a fault of the earlier systems). A tube (F) from the air cleaner (D) to the valve cover (G) routes fresh air to the crankcase. Air is pulled through the crankcase and into the hose connection (H) of a regular PCV tube and valve for routing back to the carburetor. When the Type 4 system is under zero vacuum (engine accelerating wide open) the flow of fumes through the PCV valve stops. Fumes are then able to enter the carburetor by flowing back up the fresh air inlet in the air cleaner.

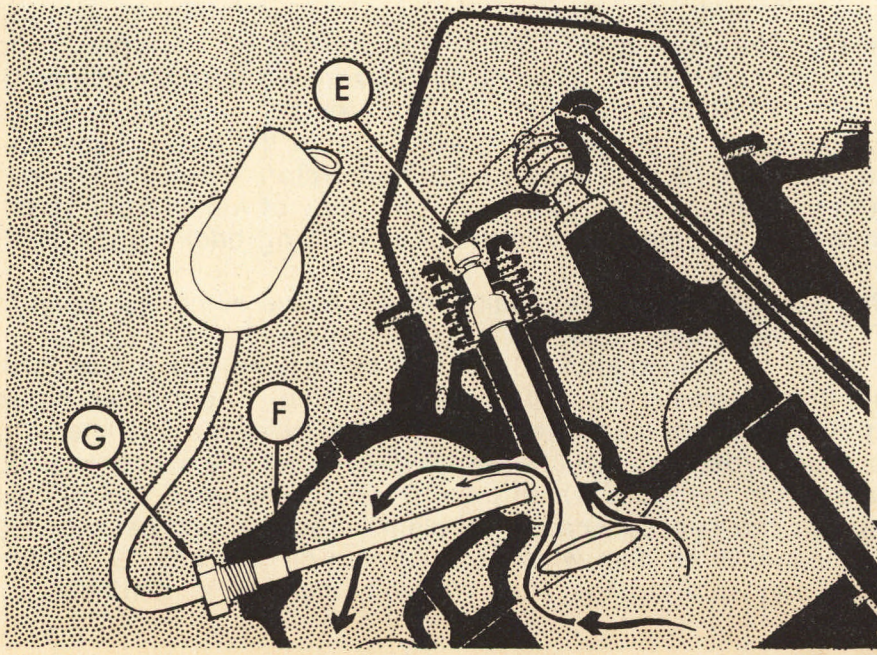
A quick check of PCV systems is included in the section on excessive oil consumption. If you suspect malfunction of a PCV system, this check will help you be sure.

Because the PCV system picks up considerable oil fumes along with the products of blowby, the hoses, valves and flame arresters are prone to clogging. The rubber hoses themselves wear out at some point, and they can become restricted by collapsing internally or by cracking. PCV valves on some types can be checked by removing them and shaking them to see if the check ball rattles. On the types which take in fresh air through the oil filler cap, clogging of the air passage in the cap can cause problems. They should be checked and cleaned in solvent. The air cleaner is an item which should also be checked. Oil vapors entering the air cleaner housing can saturate the filter element, causing a restriction on incoming air to the carburetor.

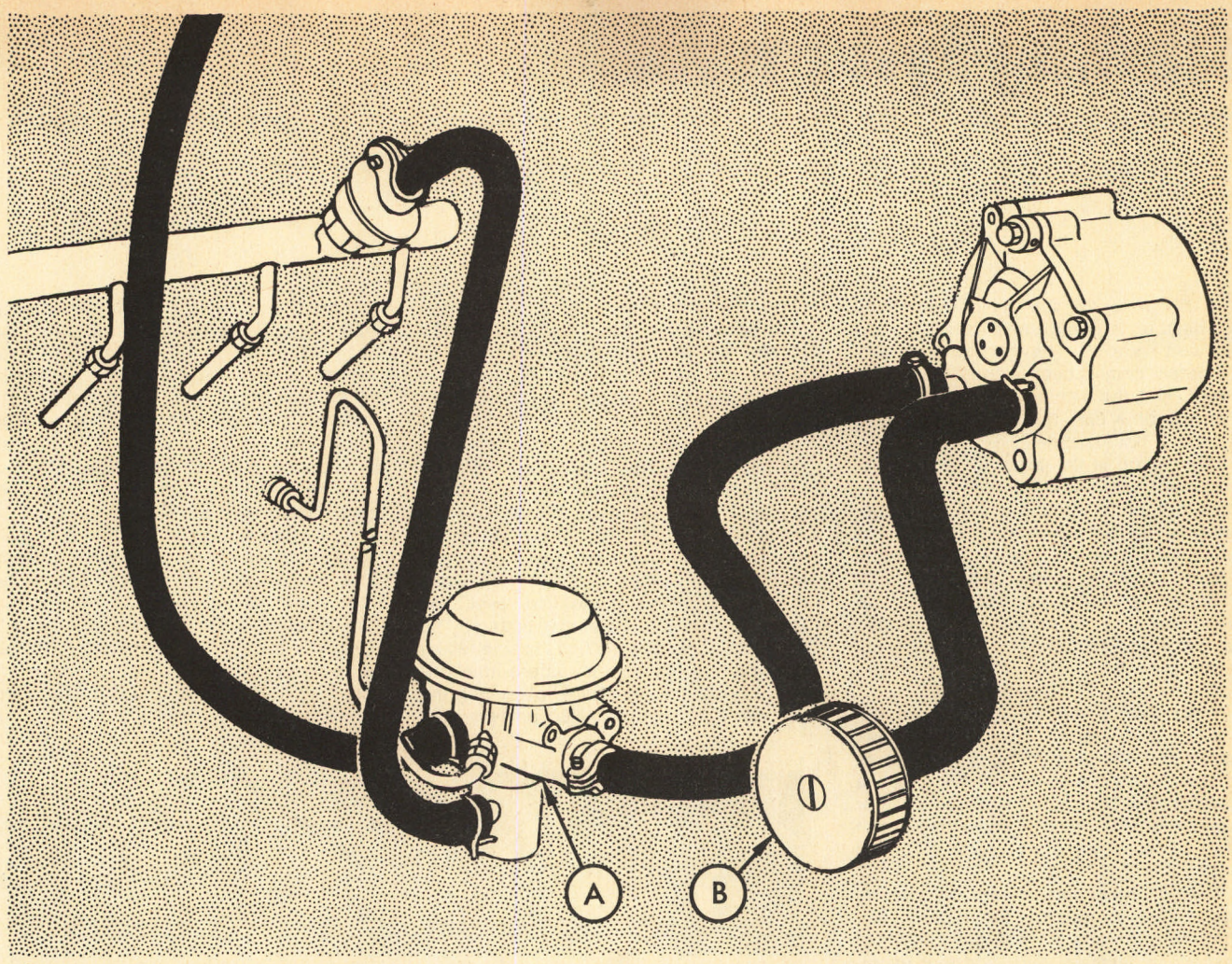
TROUBLESHOOTING EMISSION CONTROLS



A newer form of emission control is the air injection reactor (AIR). In this system, a belt-driven pump (C) provides a flow of fresh air at approximately 1 psi (pounds per square inch). The air is directed to injection tubes (B) located on the exhaust manifolds (A). The purpose of the AIR system is to direct a stream of fresh, oxygen-filled air to the point at which the exhaust gases exit the combustion chamber.



When the exhaust gases pass around the open exhaust valve (E) into the exhaust manifold (F), the stream of air entering the manifold from the air delivery tube (G) near each port mixes with it and causes it to reburn at an extremely high temperature, reducing the amount of unburned hydrocarbons. Incorporated in this system is a check valve (D), which prevents exhaust gases from getting back to the pump and damaging it.



Also a part of the AIR unit is an anti-backfire valve (A). This redirects the air from the pump when the driver lifts his foot from the throttle and prevents backfiring in the exhaust manifolds. When the gas pedal is released, the engine gets a rich mixture of fuel, which it does not burn well. This rich mixture is present in the exhaust manifolds, and if combined with the fresh air, would result in an explosion inside the exhaust manifold or pipe. The valve only operates for a moment as the driver lifts his foot from the pedal. The valve cuts off the supply of air coming into the exhaust manifold from the AIR pump until the brief period of extra-rich gas mixture passes. The system then returns to normal operation.

Troubleshooting the AIR system is not hard. The first step is to examine the belt which drives the air pump. It should be in good condition, without any glazing, cuts or signs of fraying or rotting. It should also be adjusted correctly for tension (see shop manual).

NOTE: BEARING NOISES IN AIR PUMPS ARE OFTEN DIFFICULT TO DISTINGUISH FROM NOISES IN GENERATORS AND POWER STEERING UNITS, WHICH MAY BE LOCATED NEARBY.

Some models of the pump have provisions for oiling. If so, it should be oiled periodically to be sure it turns freely. Air coming into the pump is filtered either by a small filter (B) located on the pump or by routing the air through the main air cleaner filter element on the carburetor. Pump sucking power can be checked by removing the filter and using a cigarette or match to see if the pump will draw in smoke when the engine is idling. The air pump is not an easy unit to work on. Many models cannot be disassembled without special tools. If you have a major problem, see your local mechanic.

There are a number of other emission control systems on the modern automobile engine. Some affect the operation of the ignition, others cycle exhaust gases back to the cylinders for burning. Because of the complexity of these systems and the specialized tools and knowledge involved in troubleshooting and repairing these systems, we recommend that the reader consult the shop manual on his car or see a mechanic for emission control work.

Starting System

It happens all the time. Somebody calls up a garage and says, "My car won't start." The garage man immediately comes back with, "Will it turn over?" And the owner answers, "Yeah, if I drive it off a cliff, but what's that got to do with it not starting?"

Right there is the basis for a beautiful argument, all because the car owner does not understand the difference between a car that won't start and one that won't turn over, or crank. The starting system might be in beautiful shape with a battery powerful enough to light up New York City. When the key is twisted to the start position, the engine spins faster than it does when you're driving down the road. But it doesn't start.

Then there's the situation where the battery and starter give a few weak gasps and then everything is as quiet as a calm day in the desert. In this case we say that the engine will not turn over or won't crank. We don't know if it won't start because we can't crank it to find out.

Most of the problems with the starting system are caused by the battery. Not that the battery is a weak point. It's just that it only lasts so long—and that usually isn't long enough. Suppose your car won't crank some morning. Is there any way that you can tell what is the matter? You bet there is. You can pinpoint the problem by turning on the headlights. If they are normally bright, it's likely that the battery is OK. But if they're dimmer than a candle flame in a high wind, the trouble is almost certainly in the battery or its connections.

Let's assume that your car's headlights are very dim. The next step is to determine the condition of the car's battery. If the charging system is doing its job and the battery still tests weaker than an old dry cell, you'd better start shopping for a replacement. Don't wait for a complete battery failure.

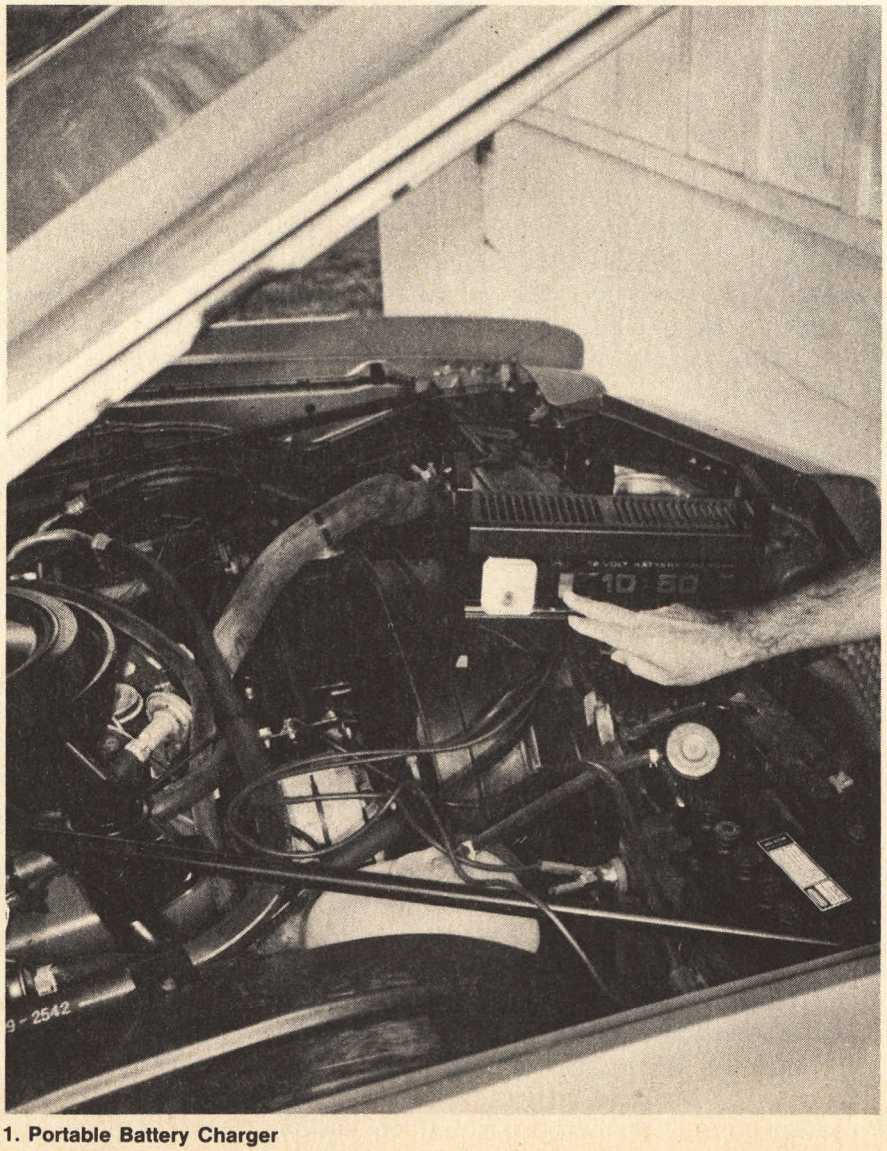
BATTERY TESTS

Several tests can be made to find out if your starting system is doing its job. The easiest and most practical is to check starting voltage at the battery terminal of the coil while the engine is cranking. You should get at least 4½ volts on a 6-volt system, or 9 volts on a 12-volt system. You should check cranking speed of the engine at the same time, either with a tachometer or a well trained ear. If the cranking voltage and speed are above the minimum specifications (published in factory shop manuals), then there is likely nothing wrong with the starting system.

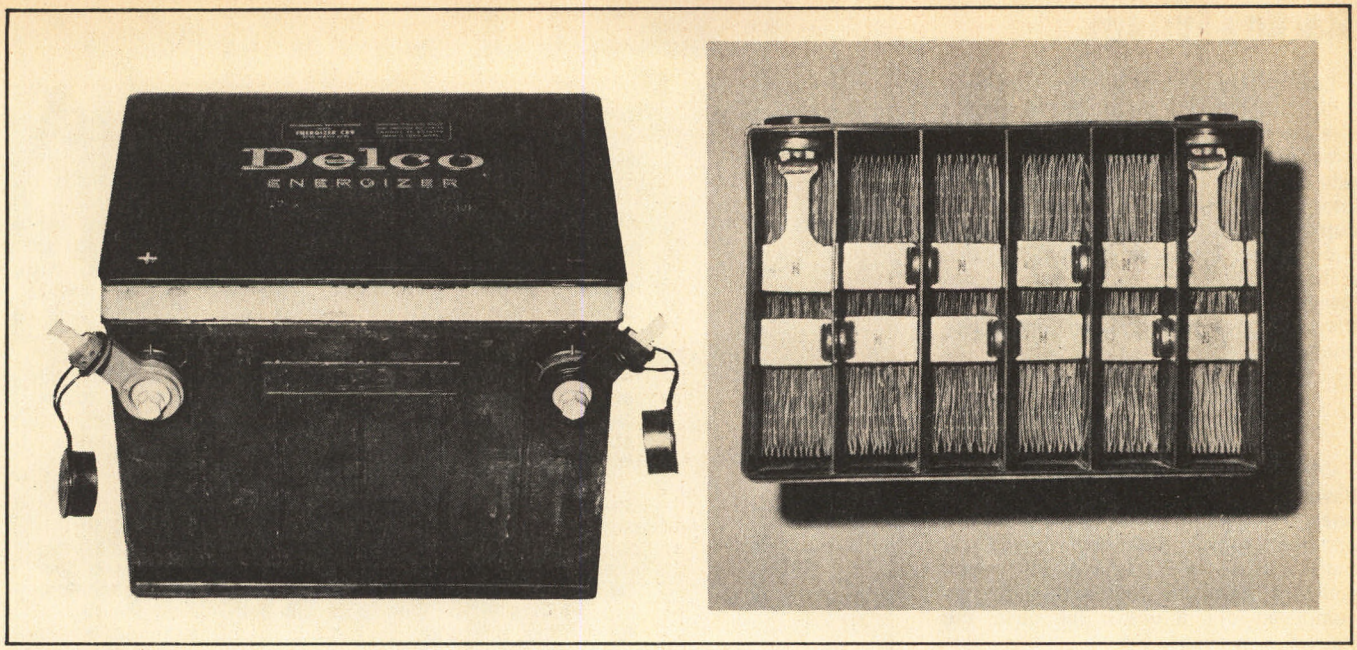
If all is not well with the cranking test, the next step is a check of battery voltage while the battery is not doing anything. It's called an open circuit voltage test, because all the circuits connected to the battery are disconnected, or turned off. Anything above 12.5 volts is considered OK. A 6-volter is OK at about 6.2 volts.

Suppose some of the above tests are marginal. Then the thing to do is make a high-rate discharge test with a battery-starter tester. However, you should not make this test if the battery is undercharged. Charge it up first, until the open circuit voltage is above 12.5 volts. If it won't charge up to that level, you know you have a defective battery. The high rate discharge test is made by drawing three times the ampere-hour rating out of the battery while observing the voltage. For example, a 60 ampere-hour battery (20-hr. rating) should be tested at 180 amps. If the voltage on a 6-volt battery stays above 4.8 and on a 12-volt battery above 9.6, then all is wonderful in batteryland. If it won't, get rid of the battery: you're flirting with a no-start situation.

Suppose the battery checks OK, but you know the car won't start because you had to take the bus to work yesterday. In that situation it might be a good idea to buy a monthly pass for the bus. But the situation is not that desperate. You know the battery is OK, so the trouble must be in the starter. If you want to check it, a battery-starter tester will measure the amount of current the starter is drawing. If it's drawing in excess of specifications, that's proof that the time has



1. Portable Battery Charger



2. Non-Fill Battery

1. A portable battery charger can return its cost in a short time. This Sears unit can be used as a 50-amp booster or 10-amp charger that automatically reduces its power flow to 5 amps as battery nears full charge.

2. The new Delco-Energizer battery is permanently liquified and sealed at the factory. The owner of this optional electrical storehouse will never have to worry about filling the cells. Vaporized electrolyte is trapped in a baffled tank above the cells where it condenses and returns to the main body of battery fluid.

come to put on your old clothes and take the starter off the engine.

Battery testing used to be a lot easier when the cell connectors were exposed on the top of the battery. Then you could test each cell with a voltmeter or a load tester.

The internal cell connectors that are now an almost universal feature of automotive battery construction do not permit access to the poles of the individual cells. *(No attempt should ever be made to jab voltmeter prongs through the cases of such hardtop batteries.)*

High-discharge tests provide useful information only after the battery has been charged, and are therefore of little value in troubleshooting. In fact, if the battery does not have at least a 50% charge, such tests can seriously damage the battery.

Hydrometer testing is a better means of checking cell condition—particularly for the backyard mechanic. Battery-testing hydrometers can be purchased for as little as 50 cents, and really excellent instruments sell for under $3 in many automotive supply stores.

In using the hydrometer, all the filler caps are first removed from the battery top and the tube on the tip of the tester inserted in turn into each cell. By squeezing the rubber bulb and releasing it, a quantity of the battery's water-and-acid mixture is drawn up into the glass barrel of the instrument. Inside the hydrometer barrel is a weighted float with numbers on it. The numbers on the scale read from 1.300 to about 1.100 and indicate the comparative weight or density of the solution. The reading is taken at the surface of the liquid in the tube.

A fully charged cell will test between 1.275 and 1.280, while a cell in good condition may be anywhere between 1.280 and 1.250. A cell in only "fair" condition will produce a reading between 1.250 and 1.225. Any reading below 1.225 indicates a poor charge and, if a cell is found to be below 1.150, the battery is for all practical purposes dead.

If the cells test in the "poor" range the battery must be given a recharge. This can be done at a service station or with one of the popular little "trickle" battery chargers that have become popular for home use. By testing the cells during charging it is possible to tell when the process is complete. As stated above, a fully charged cell will test at 1.275 to 1.280 (or even 1.300). A half-charged cell will read from 1.200 to 1.225 and isn't ideal.

If any cell is lower than the others by .050 or more, that cell is shorted and the battery's days are numbered. Also, if charging can no longer bring the cells of the battery up to at least a 50% charge (about 1.200), the battery is really shot and should be replaced immediately.

Hydrometer testing should also be a part of the routine servicing that you give your car. By testing the battery every 2 or 3 weeks, most battery trouble can be headed off before it has had time to become serious.

To get the most accurate picture of the battery's health, the hydrometer tests should be made under proper conditions. Never take readings after adding water to the cells or after a long, high-speed trip. The best readings are obtained 2 or 3 days after water has been added and the car has been driven in normal service. To make the test, the car should have been left standing for several hours or overnight. The engine is then started, switched off, and the battery given about 5 mins. to "recover." The cells are then tested with the hydrometer. Readings taken at this time will give the truest picture of the battery's actual condition.

It should be noted that temperature has a definite effect on the readings you will get with your hydrometer, due to the fact that the density (specific gravity) of the battery electrolyte changes with the temperature. When the battery is hot (in summer), the hydrometer readings will be lower; when the battery is cold (in winter), the hydrometer readings will be higher.

Readings are considered to be correct when the temperature of the battery liquid is 80° F. For every 10° above 80° you must add .004 to the original reading; for every 10° below 80° you must subtract .004. Thus, a cell that produces a reading of 1.225 might appear to be in fair condition, but if the temperature of the fluid is only 40°, the correct measurement would be equal to only 1.209—a poor figure. For accurate readings, you can measure the temperature of the battery acid before testing it. In fact, a few of the more expensive hydrometers have a thermometer built-in for this purpose.

Besides making tests, there is another way to keep an eye on the condition of your car's battery. Most present-day cars have the so-called "idiot lights" to indicate a lack of battery charging rather than the more accurate—and, of course, expensive—ammeter. The trouble with the idiot light system is that it does not tell the driver if his battery is being overcharged.

Overcharging can be very harmful to an automobile battery. The best way to detect it—short of installing an ammeter—is to make a frequent check of the water level in the battery's cells. Normally, an automotive battery requires water only four or five times per year (hot climates excepted), but if yours seems thirstier than a sun-dried sponge, it's time to check the voltage regulator before trouble develops.

Starting System

Low battery electrolyte is caused by a high charging rate because the excessive charging heats up the battery, thus evaporating the water. High charging rate comes directly from a voltage regulator that is set too high, not from the current regulator. Six-volt regulators should keep the voltage below approximately 7.2, and the 12-volt systems below 14.2. Higher voltages are permitted if they are necessary to keep the battery charged.

BATTERY CABLES AND CONNECTIONS

Of course your "headlight test" might have turned out differently. Let's suppose that the lights were quite bright and that a hydrometer test proved the battery to be in top shape—yet, when you try to crank the engine, the lights go completely out. If this is the case, the trouble is probably a bad battery cable connection.

The battery terminals are the first thing to check. As pointed out earlier, these are often subject to looseness and acid corrosion. In an emergency, you can often get started by having someone press the tip of a screwdriver into the joint between the cable terminal and the battery post. The permanent cure is to get the

BATTERY EFFICIENCY AT VARIOUS TEMPERATURES

Temperature	Efficiency of a Fully Charged Battery
80°F.	100%
50°F.	82%
30°F.	64%
20°F.	58%
10°F.	50%
0°F.	40%
—10°F.	33%

UNDERSTANDING THE NEW BATTERY RATINGS

PHYSICAL SIZE — Battery size does not necessarily indicate quality, but it's important for replacement fit. The best battery in the world won't do any good if it doesn't fit into the battery box in your car.

AMPERE-HOURS — A measurement of the amount of amperes the battery will put out for 20 hrs., ending up with 1.75 volts per cell. For example, a battery that will put out 5 amps for 20 hrs. (5 × 20) is a 100-amp-hr. battery. This 20-hr. rating is being discontinued in favor of the "reserve capacity" rating.

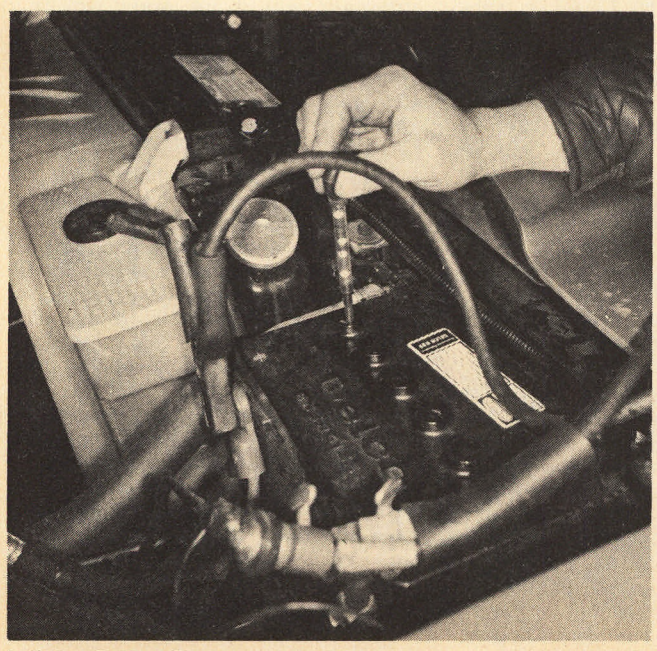
RESERVE CAPACITY — This new rating gives the number of minutes that the battery will sustain a 25-amp discharge at 80° F. and still remain above 10.5 volts. This standard gives you a rough idea of how long you could run everything in the car (about a 25-amp load on most cars) if the charging system went dead. The higher the rating, the better the battery.

0° CRANKING POWER — Given in voltage and minutes. A 150 or 300-amp load (depending on the capacity of the battery) is applied to the battery in 0° air temperature, and the voltage is measured after 5 secs. The number of minutes in the ratings is how long it takes the battery to fall to about 5 volts (specifications vary) with the same load. In both cases, the higher the reading, the better the battery. This 0° cranking power rating is being discontinued in favor of the "cold cranking power" rating.

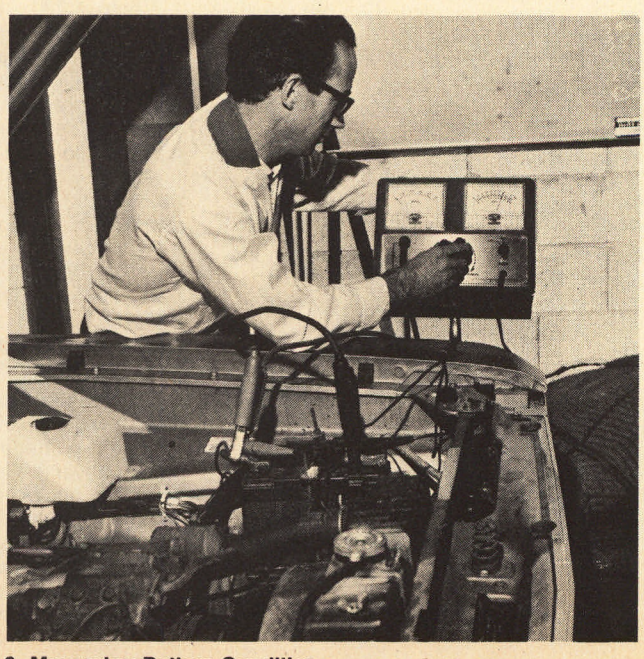
COLD CRANKING POWER — A new rating giving the amount, in amperes, that a battery can put out at 0° F. for 30 secs. In making the test, the load on the battery is adjusted until the battery voltage drops to 7.2 (12-volt battery) and then the ampere flow is measured over the 30-sec. period. The higher the rating, the better the battery.

NUMBER OF PLATES — More plates mean more active material for producing power. However, if the plates are extremely small, a battery might have a high number of plates, and still have comparatively low power. Plates are made by applying lead to a grid, so they're sometimes called grids.

MONTHS OF GUARANTEE — Can be used to figure the cost-per-month of owning the battery. This month-guarantee figure can be misleading. A battery might be guaranteed for several years, but in the last year of its guarantee it might not have the power to light a dome lamp. Therefore, it is wrong to suppose that just because a battery is guaranteed for several years, you won't have to buy another battery until that time is up. Life of a battery depends on how hard you work it, how well you keep it charged and full of water, and how it was originally constructed. Generally, the higher capacity (and higher priced) batteries will last longer.



1. Using Battery Tester



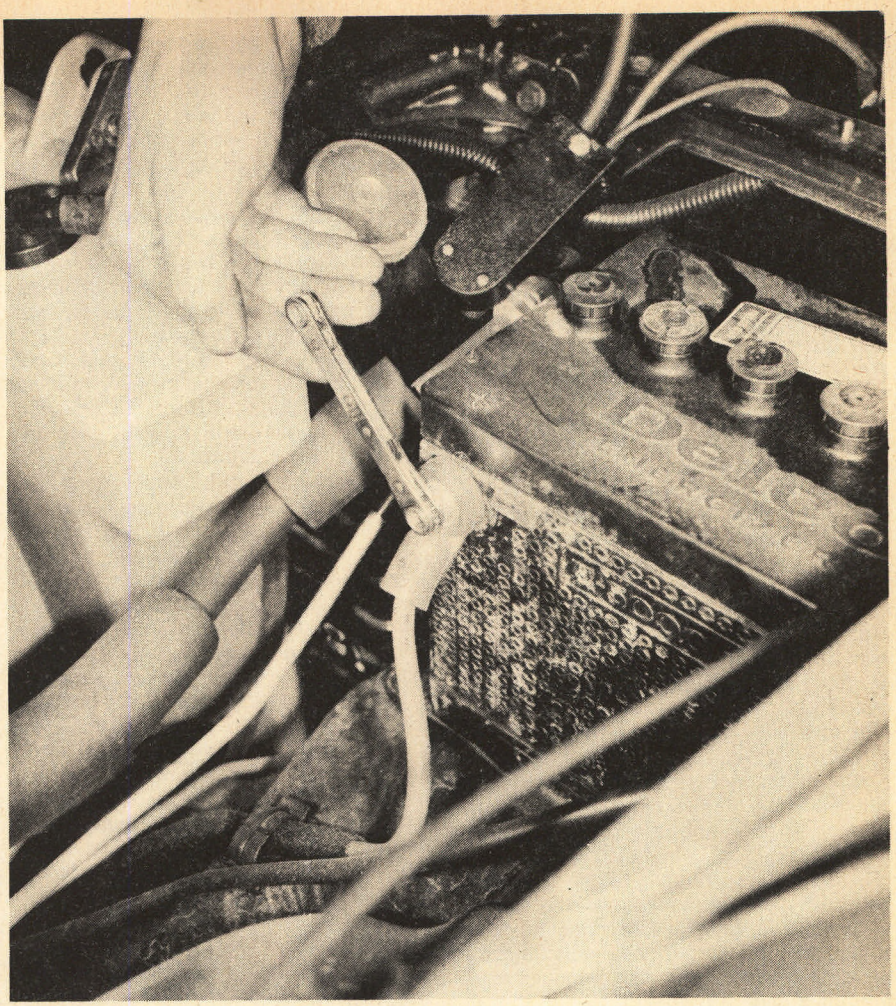
2. Measuring Battery Condition

cables into good electrical contact with the battery.

The boltless clamps used to attach cables to the battery posts on many late-model American cars are easily damaged by corrosion. Many starting problems originate right here. If the cast-in spring on these terminals has been eaten away by corrosion, the clamp must be replaced. Bolt-on types sometimes become so corroded that the bolt must be cut with a hacksaw in order to free the terminal clamp from the battery post. New bolts for these are available separately, which can save you the trouble and expense of installing a complete new cable terminal.

If the cable connections are corroded solidly onto the battery posts, a battery terminal puller should be used to remove them. These inexpensive tools work by pulling the cables straight off the post. Trying to remove frozen clamps by twisting or hammering on the terminals can cause serious damage by breaking the post's internal connection with the battery plates. Even cars that have shown no particular starting system weakness can often have their starting ability improved by removing the cable connections, brightening the terminals with emery cloth, and reinstalling them tightly. This is an especially good precaution before winter arrives.

The cables that connect the battery to the starter and to the chassis of the car are much heavier than any other wiring in the automobile. This is because the amount of current they must carry is much greater. The heavy flow of electricity necessary to start an engine would burn up ordinary wires as quickly as a burning fuse. Should some of the strands of wire forming these cables be broken, a greater load is thrown onto those that remain. Such breaks usually occur near the terminals and, quite often, spilled battery acid is to blame for the damage. If this appears to be a possible cause for insufficient current reaching the starter, or if terminals themselves



3. Removing Side-Mounted Terminals

are in poor condition, the terminals can be removed from the cable, the damaged portion can be cut off, and the terminal—or its replacement—installed.

Usually, the terminals supplied by the car maker are either soldered or crimped onto the cable. Soldered terminals can be removed by heating them with a propane torch or over a gas burner. A damp cloth should be wrapped around the cable's insulation to keep it from accidentally being barbecued. Crimped-on terminals must be cut off, discarded, and new terminals installed in their place. Replacement terminals are available which require no soldering to attach them to the cable. A portion of the insulation is simply stripped from the cable and the terminal secured in the correct place by tightening two small screws or bolts.

On some cars the ground cable connects the battery directly to the engine block. On others, the battery is grounded to the car's body and another ground strap—often located between the engine and the firewall or between the transmission and the frame—connects the engine block with the chassis. Any of these connections can provide a source of potential trouble. If there is poor electrical contact at these points due to paint, corrosion, dirt or loose connections, starting problems are as certain as a cold winter in Minnesota. A reconditioned used car that has had the engine steam-cleaned and repainted sometimes will have paint on the engine block under the ground cable terminal. This can also happen on new cars. All such ground connections should be removed from the engine or body, the mating surfaces brightened with emery cloth, and the connections re-bolted tightly together. *Poor ground contact has often been the cause of hard-to-trace car troubles.*

The battery's "hot" cable may pass through one or two switches or solenoids before reaching the starter. Follow this cable all the way to the starter and see that all connections are clean and tight. Insulation may also be worn from the cable in spots—particularly on long cables that may pass under the car. This can allow a short circuit to take place should the bare wire come into contact with the car's frame or any other grounded part. Not only would this lead to more fireworks than a flame in a gunpowder factory, it could discharge the battery to a big, fat, permanent zero. Repairing the insulation temporarily involves nothing more than wrapping the worn spot with a few inches of plastic electrical tape. This repair can later be made more durable by applying a coat of liquid rubber compound over the tape.

SOLENOID AND STARTING SWITCH

If the car doesn't crank, but the lights remain bright, or if they dim only slightly when the starter is switched on during the "headlight test," look for trouble in the magnetic starter switch or solenoid.

1. Thexton Hydro-mite battery tester is temperature-corrected to give accurate readings of battery condition. Each floating ball indicates 25% of charge; if all four float, the battery is fully charged.

2. A battery's condition can be evaluated in many ways. Most pros have testers like this Allen Battery-Starter unit. Testers like this allow the mechanic to measure the voltage level when 3 times the rated ampere-hour of the battery is drawn out. If the battery "lives" up to its rating, then a no-start problem could lie in such diverse areas as bad terminal connections, ignition or starting switches, solenoid or starter motor, or breaks in the wire.

3. Standard Delco Energizer has vent caps and must be filled periodically like any other battery. Treat its terminals with care; a 5/16-in. wrench fits cable connector and should be used to avoid rounding its corners. Tighten at 15 to 20-in.-lbs. only; if connector is tightened too much, it'll break the internal seal and cause battery failure.

Starting System

In fact, if the trouble is in the solenoid, the starter may not run at all, or may run without turning the engine.

Two types of starters are used on late-model automobiles. American Motors cars, Plymouths from the late 1950's and early 1960's, Studebakers, and many Ford products have *Bendix drive* starters. GM cars, Chrysler products including late Plymouths, VW's, and many of the later FoMoCo models employ *overrunning-clutch* types. The latter have a solenoid mounted directly on top of the starter which pushes the starter pinion gear into mesh with the engine's flywheel ring gear during the starting operation. Bendix drive starters have a pinion gear that is mounted on the starter shaft in such a way that it is thrust into engagement with the flywheel ring gear by the starter motor's rapid speed buildup. But Ford's positive-engagement starter uses the magnetic force of the starter itself to engage the starter drive and needs no separate solenoid to assist it in its function.

In cars with Bendix drive starters the solenoid is actually only a magnetic switch that connects the starter to the battery. Since it has only an electrical function, it need not be mounted on the starter, although sometimes it is. The solenoids of overrunning-clutch starters must, however, be mounted on the starter because in addition to connecting the battery to the starter, they must move the starter pinion gear into engagement with the engine's flywheel.

When the ignition is turned to the "start" position, or when the starter button is pushed, current is not sent directly to the starter. Instead, it energizes the solenoid (in Ford or GM products), which in turn connects the heavy "hot" cable of the battery to the starting motor windings. Chrysler products are slightly different. They use an additional gadget called a starter relay, mounted on the firewall in the engine compartment. In the Chrysler system, the ignition switch energizes the relay, then the relay energizes the solenoid, and finally, the solenoid makes the connection between the battery and the starter.

Solenoids can be tested without removing the unit from the car.

Using the following simple jumper cable test you can quickly condemn or exonerate the solenoid as the source of the trouble.

1) Carefully (sparks may fly and a lot of heat can be generated) connect the two large terminals of the solenoid with a heavy jumper cable. The starter should turn the engine normally. If it does not, the trouble is not in the solenoid.

2) By attaching the jumper cable between the "hot" terminal of the battery and the correct small terminal of the solenoid, it should be possible to make the starter operate normally. On some early Chrysler products, touching a hot lead to the wrong small terminal will burn up the neutral safety switch. The terminal to avoid is the one with a wire running down to the transmission. If in doubt, disconnect both small leads from the solenoid, then connect a hot lead to one small post and ground the other. If the starter operates, the trouble is *not* in the solenoid, but in the ignition switch, starter button, automatic transmission "neutral" switch, or it could be in the wires connecting these controls with the solenoid.

The magnetic switch (often called a solenoid) on Ford cars with all types of starters usually has two small terminals. The "hot" jumper should be connected to the one closest to the large terminal whose cables go to the battery.

3) If connecting the "hot" side of the battery to the solenoid's small terminal causes the starter to run, but does not turn the engine, the trouble is in the starter drive mechanism.

4) Assuming that the battery tests OK, and none of these tests gets a reaction from the starter, try connecting a heavy jumper cable directly between the battery's "hot" side and the solenoid terminal that leads to the starter or to the terminal on the starter itself. If this does not cause the starter motor to run, the trouble is in the starter—not the solenoid.

When making the above tests it is neither desirable nor necessary to have the ignition turned on. However, when using jumper cables there is always a chance for accidental contact with other electrical connections. For this reason, it is *always* advisable to disconnect transistor ignition systems and alternators before making jumper cable tests, since accidental shorts can destroy these units instantly.

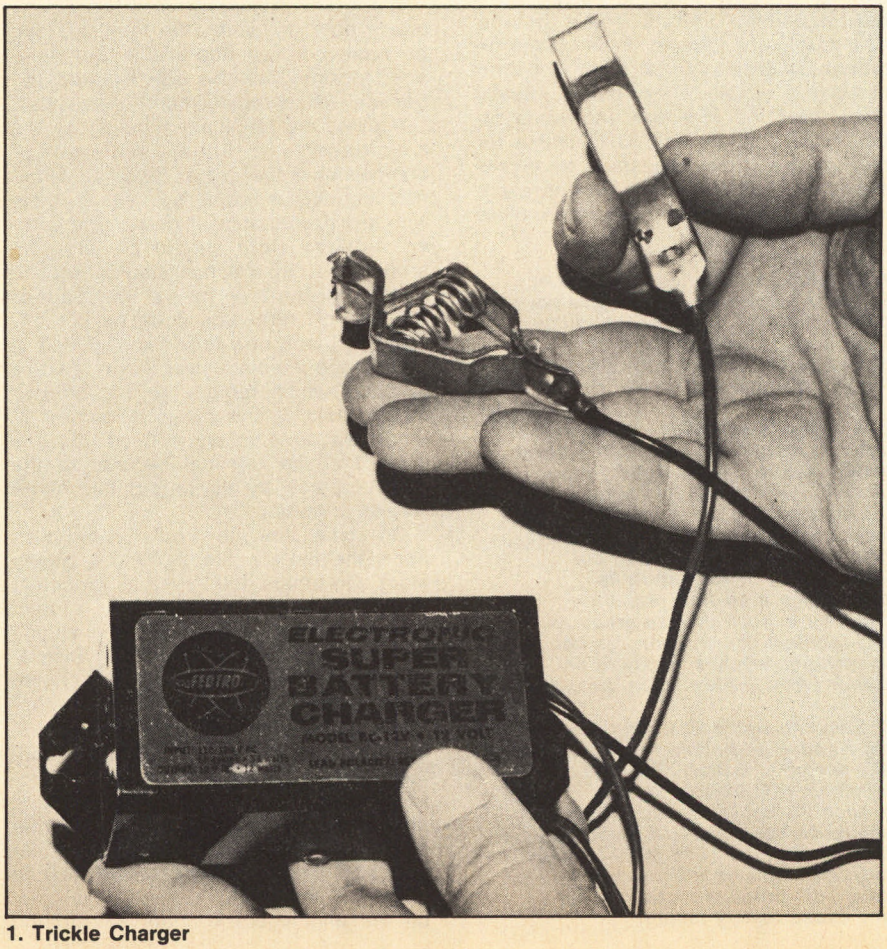
You must also be extremely careful about making any sparks near a battery. Whenever a battery is being charged, hydrogen gas is created in the cells above the electrolyte. This gas can stay there a long time, even when the car is not being operated. All it takes is one spark to set it off, and you have an exploded battery, with everything nearby drenched with sulphuric acid. When connecting jumper cables, make the connection to the hot battery post first, then connect the ground jumper to someplace away from the battery, such as the engine block. If any sparks fly when you connect the ground, they will be far enough away from the battery to keep from blowing it up.

If the tests do prove the trouble to be

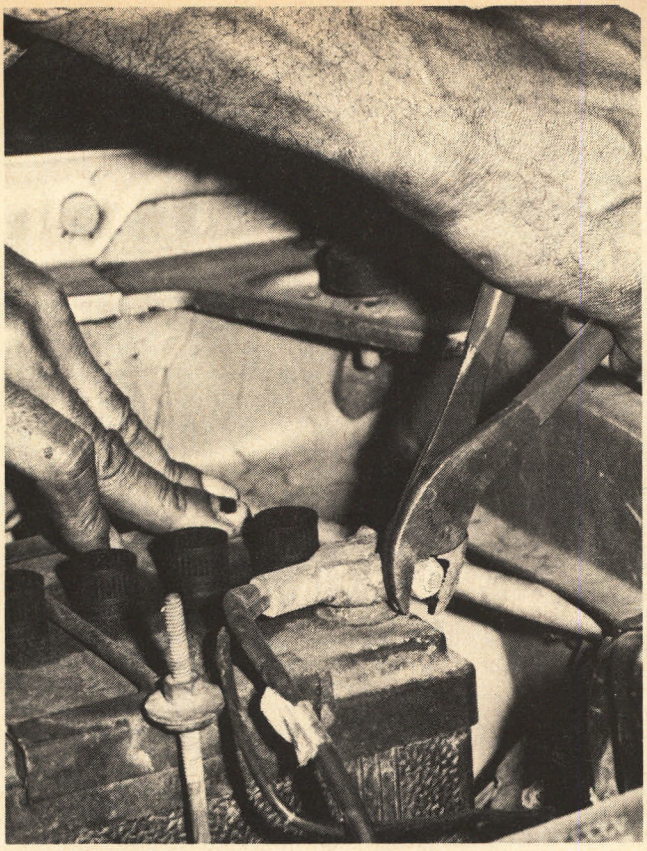
1. Any do-it-yourselfer can easily afford an inexpensive "trickle" charger to augment his lack of taking long, battery-charging trips. These units, however, cannot rectify the problem of a "used up" battery or a malfunctioning voltage regulator.

2. S-K battery pliers, with their thin jaws set at a 30° angle, will go a long way to end the threat of rounding off the flats on the nut of a battery terminal. Never pound or violently twist the terminal to free it from the post. Chances are you'll damage or break internal connection.

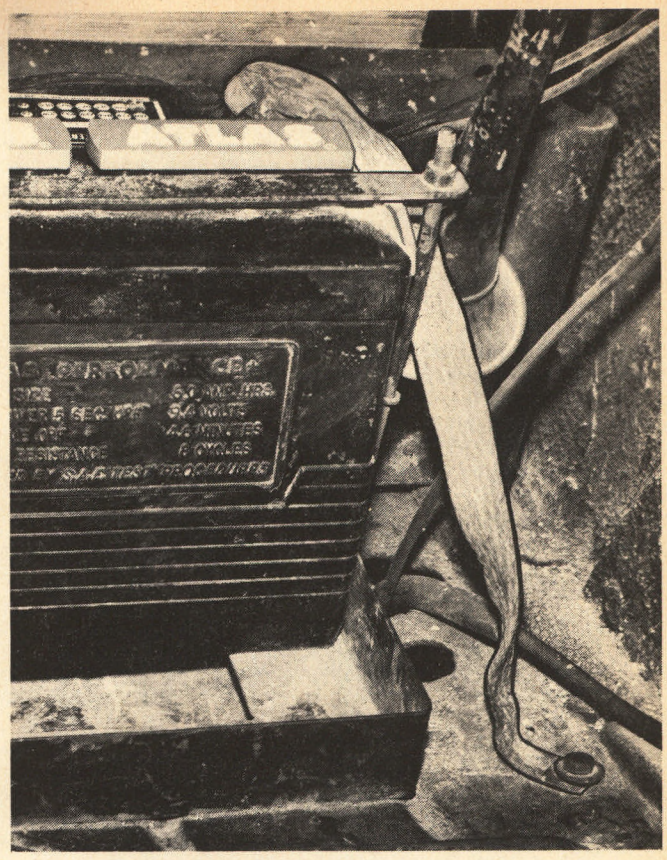
3. Some motorists have experienced hard starting problems which were ultimately traced to poorly grounded battery and/or starter motor. Always make sure the battery and starter ground strap is securely attached to your car's frame.



1. Trickle Charger



2. Battery Pliers



3. Battery Ground Strap

in the starter solenoid or magnetic switch, the only repair practical in some cases is to replace the entire unit since they may be sealed assemblies. However many units, such as the Delco solenoids on GM cars and many Ford trucks—as well as some of the magnetic switches used by Plymouth—*can* be disassembled. In these, the internal contacts can be examined and repaired. If the contacts are in good condition and the plunger works freely, the solenoid *should* work. If it does not—sorry, the windings are probably burned out.The exact condition of the windings can be checked with an ohmmeter or with a battery-powered tester.

To repair the starter solenoid on a 4- or a 6-cylinder inline engine it is not always necessary to remove the unit from the car, but on most V-8's the solenoid is otherwise inaccessible. In some cases it's necessary to remove the starter before you can get at the solenoid at all.

SOLENOID REPAIR

Firewall-mounted solenoids must be replaced, but the type that is mounted on the starting motor can be repaired.

If the solenoid is coated with grease and road dirt, it should be thoroughly cleaned before removing the cover from the contact points. Otherwise, dirt may get onto the contacts to cause trouble later. Except to remove the battery cable and the small wire from the dashboard starter control, it is not necessary to take any of the other nuts and washers off the terminals. In most cases there is just one small screw that holds the dust cover in place. After removing it, the cover can be lifted off the solenoid's contact assembly. Some late Delco solenoids have two screws holding the cover in place. The cover on these also contains the stationary contacts, so remove it very carefully.

If they are not attached to the cover itself, the contacts can be dismounted from the body of the solenoid by undoing two small screws. Once these are out, the stationary contact assembly can be lifted and pushed to one side while still connected to the wires that enter the body of the solenoid. The assembly can be further dismantled by taking off the nuts holding the contacts, but this is only necessary if you have purchased a rebuild kit that contains new contacts.

The contact disc—a large brass washer that moves against the stationary contacts—can become quite pitted and worn, as can the stationary contact to which the battery cable is attached. If the battery contact and the contact disc are not badly burned, but only coated with dirt and deposits, they can be sanded or filed smooth. However, if the contacts are causing starting troubles, it is likely that they are worn quite badly. In most of these solenoids it is not necessary to file the contact surfaces flat nor to replace the parts. By simply removing a snap retainer, the contact disc can be taken from its shaft and turned over. This puts the "new" side of the disc toward the contacts. Similarly, the battery contact retaining nut can be loosened about 3/16-in. and the contact rotated 180° to put its "good" side under the contact disc. The other contact cannot be turned since one of the wires leading to the solenoid windings is welded onto it. However, this contact seldom wears as badly as the other, and it can quite easily be restored to like-new condition by a few strokes with a file. Complete contact assemblies and solenoid rebuild kits are also available at very moderate cost at auto parts dealers.

If your jumper cable tests seem to indicate that there is a burned-out winding in a starter-mounted solenoid, always remove the dust cover and check the wires connecting the windings to the contacts. In a few cases what have appeared to be burned-out solenoids were able to be returned to service after a simple wire repair. It's always best to check this before tossing the unit into the trash can.

When reassembling the solenoid, make certain that the contact shaft and the plunger work smoothly. A binding contact can produce a no-start just as quickly as a flat battery. If the plunger has been left attached to the starter drive, don't tighten the bolts that hold the solenoid until it has been aligned to allow the plunger to move effortlessly.

After cleaning and reassembling the solenoid, ground the case and connect the small terminal to the "hot" side of the battery. There should be a click as the solenoid coil moves the plunger into "contact" position and another click when the connection is broken and the spring causes the plunger to retract. If there is no click, the windings are defective, which means a new solenoid must be installed.

STARTING SWITCH TROUBLES

If the car's solenoid checks out all right, but trouble is indicated in the circuit that connects the dash control to the solenoid's small terminal, there are a number of possible malfunctions to be considered. The most likely trouble spot is the ignition switch itself in cars

equipped with "key" starter controls. This switch is used at least twice every time you drive your car. Consequently, considerable wear can take place—especially if the lock and cylinder are never lubricated. Key-starter switches are sealed units which must be replaced in their entirety.

If you suspect that the reason for a no-crank condition is the key switch, disconnect the plug at the back of the switch and connect a jumper between the hot terminal and the terminal that operates the starter. If your no-crank condition disappears with the starter suddenly springing to life, you know that the problem was in the key switch. A wiring diagram will help you find the right terminals and wires without having to trace the wires from one end to the other.

To remove the ignition switch from the dashboard, any individual wires should be carefully disconnected from the back of the switch and labeled to facilitate their installation on the new unit. If there is a plug, free the locking tangs and unplug it. The ground cable should be disconnected from the battery to prevent shorts during the switch-changing job. After the wires have been disconnected the switch can be removed from the dash. This is done by unscrewing the retaining ring that surrounds the lock cylinder. A special wrench will fit the slots in the ring, or pliers may work. Care should be exercised to avoid marring the dash or the ring. It isn't necessary to change the key and tumbler portion of the switch. It can be inserted into the new switch. But in some designs you have to remove the tumbler barrel before you can unscrew the retaining ring from the instrument panel. The clue is a small hole in the front face of the switch near the keyhole. Shove the end of a paper clip into the hole while you turn the key, and the whole key and locking mechanism will come out into your hand. Then you can unscrew the retaining ring and remove the body of the switch.

Installing the new switch is simply a reversal of the removal operation. If the terminals on the wires are corroded, they should be brightened with abrasive cloth before reconnecting them.

Battery current is supplied to the starter button or ignition switch by a wire that first passes through the ammeter, or perhaps a circuit breaker, relay, or junction block. Locate the "hot" wire behind the ignition or starter button and trace it to determine if it comes from the ammeter or any other electrical unit. By attaching your jumper to both terminals of each component you can bypass them temporarily. If the key or starter button operates the starter normally with the jumper in place, but not with it disconnected, then the trouble is an open circuit in the electrical unit being bypassed.

If one of these units is the source of your trouble it will probably have to be replaced. The jumper wire can be temporarily left connected across the terminals so that the car can be driven until a replacement part is located and then installed.

Late-model cars have the ignition "switch" in the steering column. If you suspect a bad switch, the column-mounted cars can either be a blessing or a chamber of horrors. To find out if your particular car is a blessing, look on the steering column between the instrument panel and the floorboards. If you're lucky, you will find your ignition switch mounted on the column with two bolts, and connected by a rod to the key lock up near the steering wheel. Removing the switch is easy, because the wiring unplugs and the two bolts are all that holds the switch in place. The switch mounting holes are slotted so you can get the switch slide in the same position as the lock.

Chevys are a special case. Their ignition switch is on the lower part of the column, but not low enough to remove it without dropping the column. That's right, you have to take off the two nuts that hold the column to the dash and lower the column until the steering wheel rests on a block that you have placed on the seat. Without the block, the column might come down far enough to break off the little string that runs up to the shift indicator. Once you get the column down, it's obvious how the switch comes off.

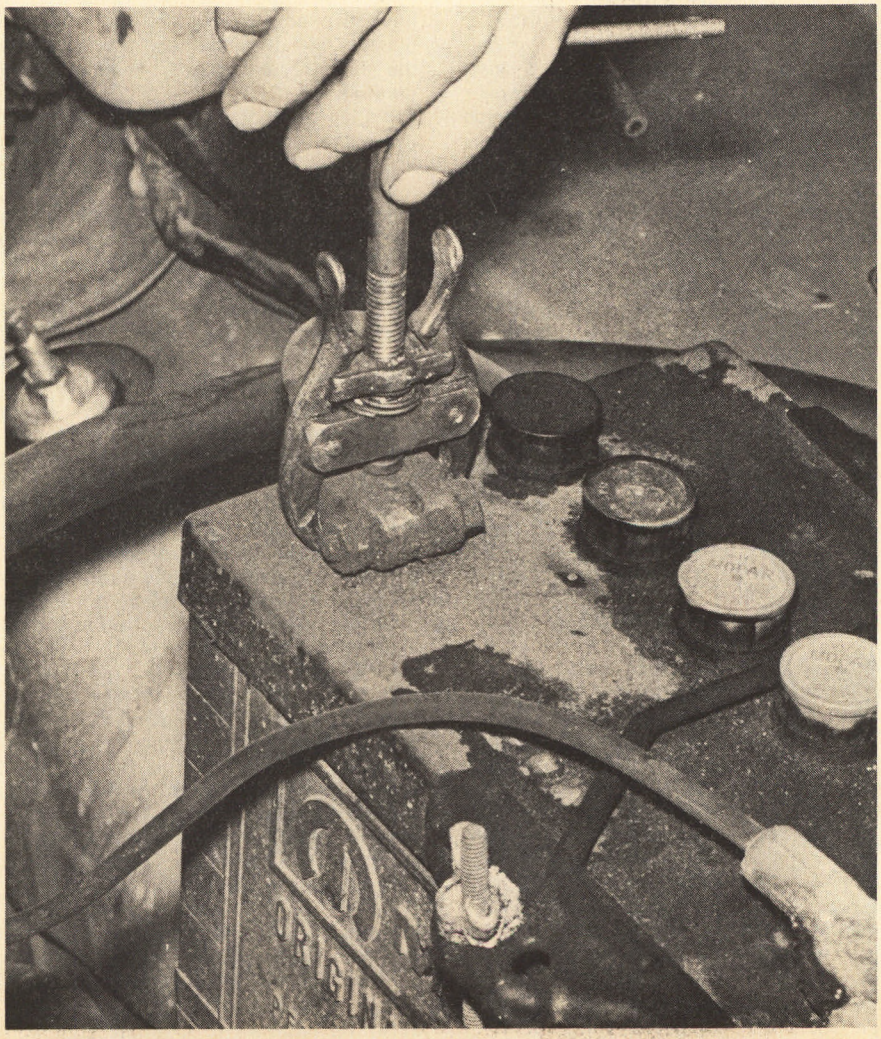
If you don't have the switch on the lower part of the steering column, then your personal chamber of horrors is that complicated area under the steering wheel. The wheel must be removed, and sometimes part of the top end of the column, in order to get the switch out. It's not an impossible job, but we suggest you have the shop manual for your car before you tackle it.

Another potential trouble spot is the "neutral safety" switch found on cars with automatic transmissions. The purpose of this switch is to make it impossible to start the car unless the selector is in the "N" or "P" position. Needless to say, this switch also receives a great deal of wear. Also, since it is frequently located at the lower end of the steering column or under the car, road splashes can eventually take their toll. Many cars have the neutral safety switch conveniently mounted on the steering column

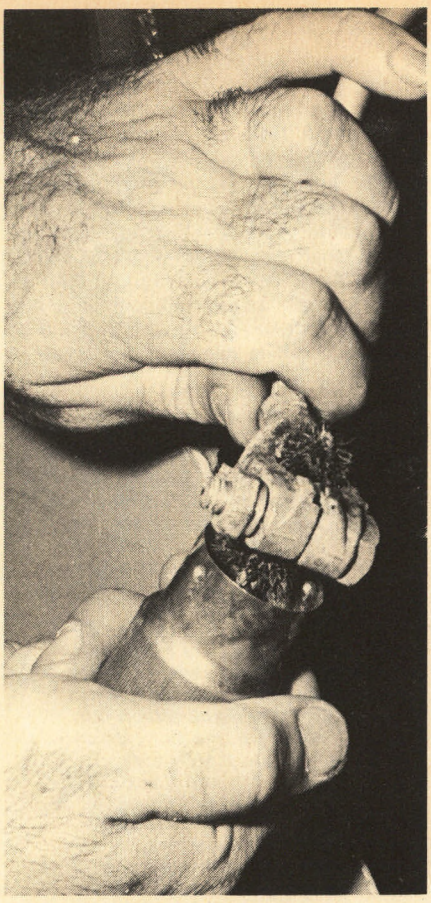
1. The best way to break 'em free from each other is to first loosen nut, then use a cable puller to lift offending terminal off the post.

2. Some no-start situations can be attributed to terminal looseness or acid corrosion. Baking soda and water will clean off most of the buildup, but you'll need a stiff wire terminal cleaning brush to finish the job.

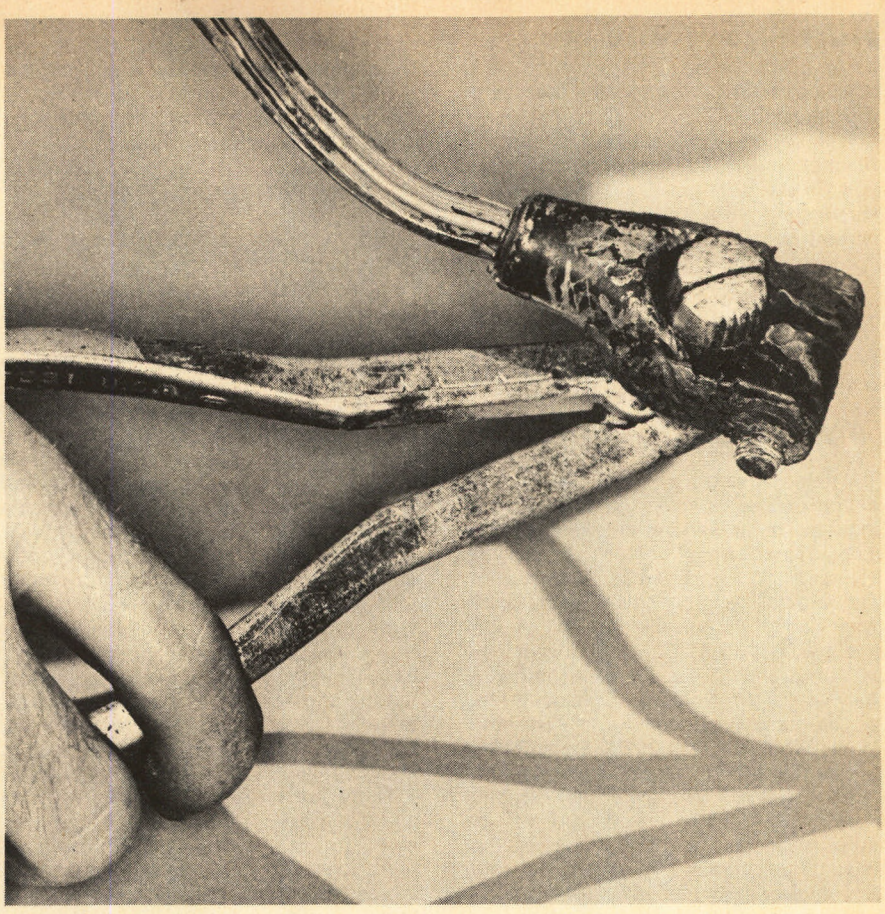
3. Spreader pliers should be used to increase the inside diameter of a terminal so it will fit over post.



1. Cable Puller



2. Cleaning Corroded Terminal



3. Spreading Terminal

just below the instrument panel. The switch holes are slotted so you can get it in the right position to allow the car to start in park or neutral only. On some automatic transmissions—such as on Chrysler Corp. cars—the neutral safety switch is located on the transmission itself and can be reached only from under the car. After bypassing the switch with a jumper (making sure the transmission selector is in neutral or park position), it should be possible to start the engine normally if the trouble is in the neutral switch.

Although it is the most likely suspect, the neutral switch itself may not be the actual culprit. An incorrectly adjusted shift linkage can produce the same symptoms. Neutral switches that work off the end of the selector shaft can be checked for improper action of the transmission linkage. However, about all you can do with the "plug" type switches on Chrysler Corp. cars is replace them—since that's where the trouble usually is. Then if the new switch doesn't work, but the jump wire will, you'll have to get the shift linkage adjusted at a transmission shop.

Neutral safety switches that screw directly into the transmission are made with a hex that allows them to be removed with a thinwall socket. Those that mount at the end of the steering column or are actuated by the linkage arms on the transmission are detached by the removal of two or three screws.

STARTER DRIVE DIAGNOSIS

If the starter motor runs normally when the dashboard control is actuated but fails to turn the engine, the trouble lies in the starter drive assembly. There are several other symptoms of drive trouble in addition to this, however. Horrible grinding noises accompanying starter operation are reason for immediate attention. Continuing to use the car will only lead to further damage to the starter drive and to the teeth of the flywheel ring gear. If there is a grinding sound, but the engine does not turn, it could mean that the engine or transmission will have to be pulled and the flywheel gear replaced, but the trouble could also be merely a broken overrunning clutch, in which case you could make the repair.

Sometimes the starter drive pinion gear will jam in the engaged position. If the car's engine is running you'll probably be able to hear an unusual noise which is the starter or starter gear being driven by the engine. If the drive jams during starting, the engine probably will not turn but a groaning or humming sound will be heard from the starter as though it was trying to turn the engine but lacks the power. Bendix drive starters are far more likely to jam than positive-engagement types. A jammed drive can be freed by putting the transmission into high gear and rocking the car forward and backward. This is not possible with an automatic transmission of course, and the starter must be removed to free the drive.

STARTER REMOVAL

If the drive assembly is not functioning properly, it will be necessary to remove the starter from the car on all but a very few engines. Even then it is usually far easier to make repairs with the starter out and on the work bench.

Start by disconnecting the battery, then the cables and wires from the starter or solenoid terminals. Locate the bolts that mount the starter on the flywheel housing (*not* the long bolts holding the starter together) and remove them. Undo the bolts under the starter first and those holding the top of the starter last. When the last bolt is almost out, the starter should be supported in some way to keep it from falling. It may be necessary to tilt the starter slightly to clear the starter drive around the flywheel.

On some V-8's it is necessary to remove the exhaust pipe or jack up the frame slightly so that the starter will clear the upper front suspension arm as the starter is withdrawn. After the starter is out, look into the opening in the flywheel housing and inspect the condition of the ring gear. The flywheel may be turned by prying with a large screwdriver. If it is stripped or broken the car will have to go to a garage for repairs.

STARTER DRIVE REMOVAL

Starters with Bendix drive need not be further disassembled when you work on the drive assembly unless there is a separate housing surrounding the drive and pinion as on some Ford-Autolite models. Delco, and other positive engagement starters, must have the long bolts that pass through the starter taken loose and the housing surrounding the drive assembly removed. It is also mandatory that the starting drive actuating lever be unbolted to allow the drive assembly to slide off the starter shaft. The solenoid

need not be dismounted from the starter for removal.

The Bendix drive assembly found on American-made starters is held in position on the armature shaft by a locking screw and two keys. Using a large screwdriver, compress the starter drive spring slightly at the end toward the starter motor. It is then possible to get at the locking screw and remove it. Some very early Ford starter drives can also be taken apart and individual parts can be replaced.

STARTER DRIVE INSPECTION

Whether the drive is an overrunning-clutch or Bendix type, the first thing to look for is broken or cracked springs. The overrunning clutch should be checked for proper action. It should be possible to turn the pinion gear clockwise (counterclockwise on VW's), but not in the opposite direction. Inspect the bushings inside the drive assembly. If they are badly worn the drive may bind or slip out of engagement.

All Bendix drives should be checked to see that the pinion gear turns smoothly as it slides in and out on its spiral-cut "worm." By looking inside, you may be able to locate small broken pieces that indicate an internal failure. It is extremely important that the drive assembly operates without the slightest binding.

Inspect the pinion gear for burrs and worn or chipped teeth. Also, look for bent tangs on the drive spring.

In many cases, starter drive trouble is due only to dirt and old grease preventing proper operation. However, overrunning clutches on U.S. and VW cars should *never* be cleaned with solvent, since they are packed with a special long-life grease at the factory. Solvent cleaning would remove this.

Bendix drives should be cleaned in kerosene but no additional lubrication applied, since oil on the "worm" could attract dirt and grit which would interfere with its smooth operation. If the worm is cleaned in solvent, then a light oil mist should be applied to the worm.

Unfortunately, all recent American starter drives—both Bendix and overrunning-clutch types—are serviced only as complete units. Any broken, worn, or damaged parts mean replacement of the entire assembly.

When a new overrunning-clutch drive assembly is installed, make certain that the starter shaft is clean and free of rust and corrosion. This will contribute to smooth action and a longer life for the new part. Rust spots can be polished away with fine steel wool and crocus cloth.

After the drive assembly and the starter have been put back together, check to see that the parts work correctly and effortlessly before reinstalling the starter on the engine.

It should be noted that the Bendix-type "*Folo-Thru*" starter drives on Ford cars have an internal lock pin that keeps the pinion from moving on the worm once it reaches full-engaged position. This pin will not disengage unless the starter is mounted on the engine and the engine speed reaches 310-390 rpm. Occasionally, a person who is not aware of this thinks that the drive unit is faulty because the pinion does not retract by hand, but it is perfectly normal.

STARTER MOTOR

Until now we have only talked about those parts of the starting system that *control* the starting operation. Now it's time to take a look at the part that does the actual work—the starter motor. Starter motors are normally a very dependable part, and most of the common troubles that interfere with their operation are elsewhere in the system. The types of troubles that strike the motor itself are likely to be simply the result of normal wear. Most such problems are capable of being coped with by the backyard mechanic. However, starters that have operated under some abnormal conditions can have certain internal electrical defects that call for the attention of a trained service man. You can usually save money in such cases by simply turning the starter in on a rebuilt one. Still, you should know how to check out the starter if for no other reason than to know if it should be scrapped.

There are three or four tests you can make of starter efficiency, with the starter off the car. We assume you have already checked cranking voltage, cranking speed, and starter current draw, and found something wrong. Or maybe you suspect something is wrong, but you don't have the equipment to check it out. In either case, let's get the starter off the car and take a look at it.

The first test is to rotate the armature by hand and feel for any dragging. Many starters fail because the bushings or bearings wear and allow the armature to drag on the fields. If the armature does not spin freely, then you've found the problem.

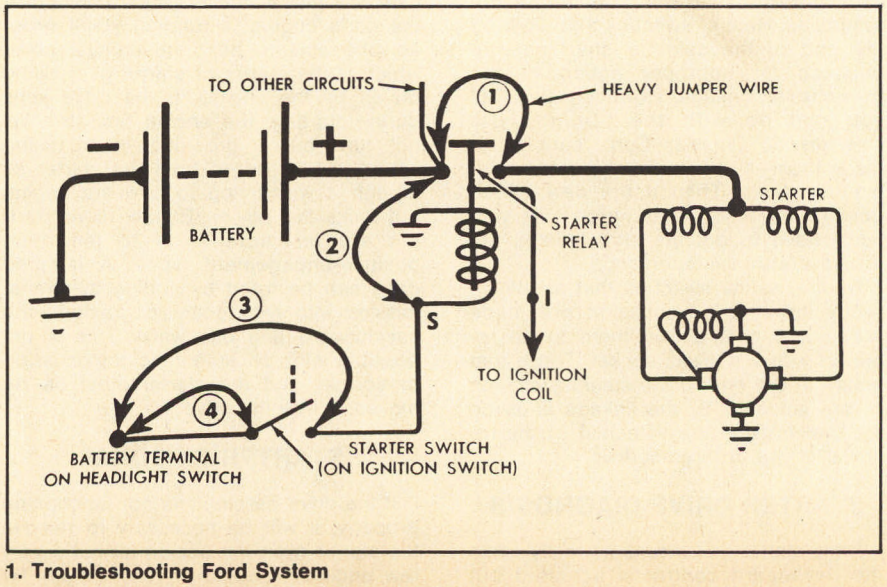
The second "test" is to check for worn bearings. Wiggle the shaft from side to side. If there seems to be a considerable looseness, try rotating the shaft while at the same time exerting heavy side pressure. If there is extreme binding or mechanical interference, the bearings will need attention.

On some starters, the bushings that support the starter shaft cannot be replaced and an entire new end plate must be obtained. However, in most cases the bushings are removable. The bushing at the flywheel end of the starter can be quite easily driven out with a piece of round steel somewhat larger than the starter shaft or with a regular bushing driving tool. A new bushing can then be installed in its place. Lubricate the outside of the new bushing so that it will go into place with a minimum of binding. A

1. Troubleshooting your starting system (like on this Ford) isn't hard, if you know what you're looking for and where to place a heavy-duty jumper cable. (1) Your solenoid is OK if, when you "jump" the two large terminals on the starter switch, the starter works normally. (2) When you connect the hot side of the battery (+post) to the small terminal (S) of the solenoid and your starter works, you have problems in the ignition switch, starter button, neutral safety switch, or wiring. (3) If when you attach the jumper cable from the hot side of the battery to the starter side of the ignition switch and the starter motor turns, you've got problems in the ignition switch area. (4) If a jumper placed here allows the ignition switch to start the car normally, you've got troubles in the wire to the switch. By the way, if your starter motor clicks as if the battery is dead (but you know it's fully charged) yet finally makes contact and lights your engine off, either your solenoid or switch is going away and should be replaced soon.

2. These are the two basic external types of solenoids or starting switches. At bottom is GM unit, attached to the top of the Delco-Remy starter. The one at the top is a Ford starter switch, usually placed somewhere on the firewall.

3. Many Ford ignition switches look like this. When plugging in the connector, make sure the locking tabs are fully engaged.



1. Troubleshooting Ford System

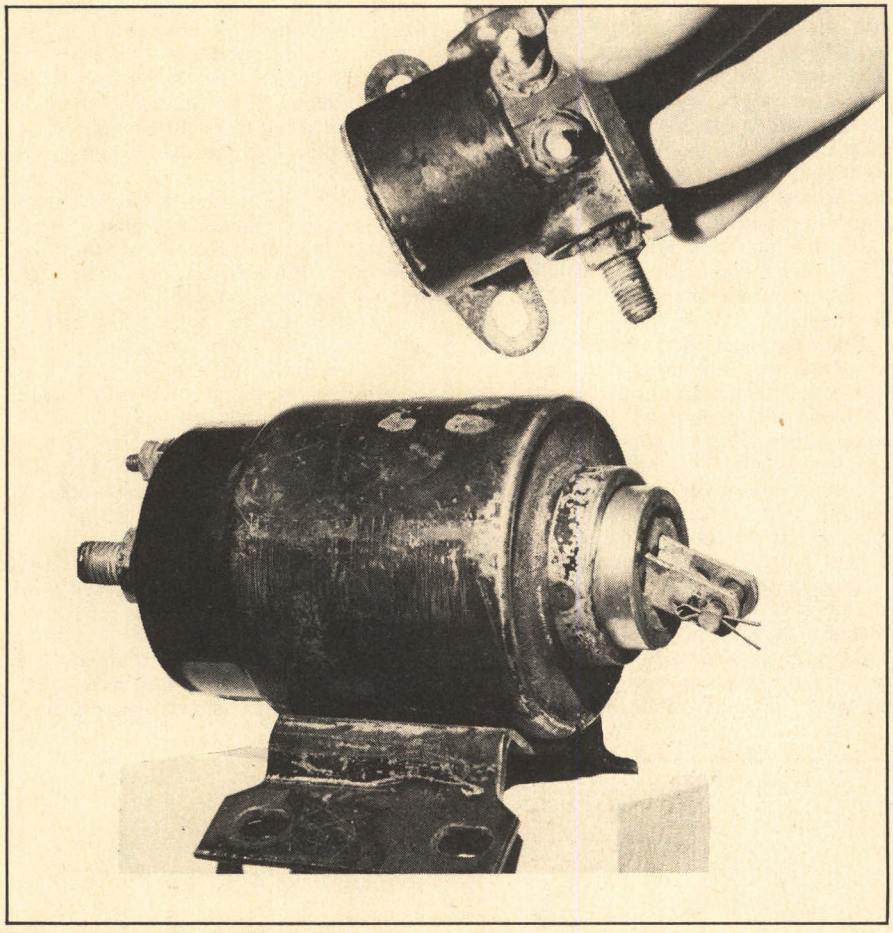
block of wood should be held against the end of the bushing (if a bushing driver is not available) and tapped *lightly* with a hammer until the new bushing is seated. The bushing in the other end of the starter presents more problems since the bearing end is capped and the bushing cannot be driven out. Some starters have a removable bearing cap that must be replaced along with the bushing, but in most starters the bushing must be cut out with a hammer and a small sharp cold chisel before the new one can be put in. There are tools available that thread themselves into these bushings so that they can be pulled out, but at $10 you'd spend more on the tool than you'd save by not buying an entire end plate which has a new bushing in it. Always have the new bushings on hand before taking out the old ones. Replacements may not be available for your particular starter.

Finally, a starter "no-load" test should be performed before disassembling the starter—providing all seems normal when turning the armature shaft by hand. The no-load test is a bench test only and cannot be made with the starter mounted on the car. It also requires an ammeter which will register up to 200 amps for Bendix drive starters and up to 500 amps for Ford positive-engagement overrunning-clutch types. The positive engagement Ford starter has an initial high current demand because the drive is being actuated by the starter's windings.

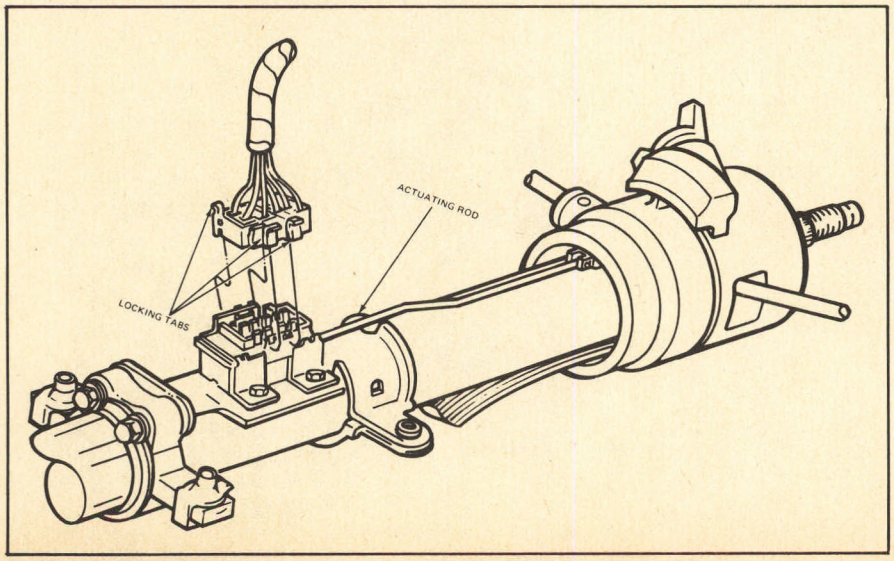
With the starter running, the ammeter should indicate approximately 0-80 amperes, according to the car maker's specifications. This should be the *maximum* for a 12-volt system. Higher readings indicate such faults as shorted windings, a rubbing armature, tight bushings or a bent armature shaft. If the starter fails to run and the ammeter registers zero, the trouble is likely open windings or worn-out brushes.

You can perform the same test *without* an ammeter by simply using two jumper cables. Connect the positive cable to the starter terminal and the negative cable to the starter frame. This should be reversed if the starter is from a car with positive ground. Of course, you will not be able to check for shorted windings as you would with an ammeter, but you will find out if the starter runs at all. Also, if it seems to turn slowly, a bent shaft, tight bushings, or rubbing armature can usually be detected. If these conditions are not present, the slow running just *might* be the tip-off that there's an armature short.

In the days of manual transmission cars, it was easy to perform a starter lock test by putting the car in gear, applying the brake, and operating the starter. A certain amount of current would flow through the starter, and it could be measured with an ammeter, then compared with specifications. In these days of automatic transmissions, the lock test can only be done on a starter test bench, and they are scarcer than males at a Women's Lib meeting.



2. Solenoid and Starter Relay Switch



3. Ford Ignition Switch

STARTER MOTOR DISASSEMBLY

The same long through-bolts that release the drive housing also allow the starter to be opened up once they are loosened and taken out.

After the through-bolts are out, you will be able to remove both ends from the starter motor. The drive assembly must also be removed as described earlier. The other end plate contains the brush holders, and therefore the brushes must be lifted out before the end plate can be taken off. This is also a necessary operation prior to replacing the bushings in the end plate. The two ground brushes can have their wires unscrewed from the starter frame and the brushes left on the end plate if desired. The brushes on Delco starters are attached to the brush holders with screws. After the end plate is off, the brush holders and springs should be removed from it and the mating surfaces cleaned thoroughly before the new brushes are put in. A word of caution: *do not* clean inside of case with solvent as it will damage armature and field coil insulation. Merely wipe off with a clean cloth.

If the commutator was not checked earlier, it must be supported on "vee" blocks and rotated against a dial indica-

tor or a reference block that can have the clearance checked with a feeler gauge. If the commutator is found to be eccentric, the armature must be chucked in a lathe and *very light* cuts made across the face of the commutator until it is once again round and concentric with the shaft in its center. After turning the commutator on Delco starters, the mica strips separating the brass segments of the commutator should be under 1/32-in. using a section of hacksaw blade. The undercutting should also be about .002 wider than the insulation strips. On Autolite starters, the commutator is polished with #00 or #000 sandpaper to remove all burrs left by the turning operation. Autolite also recommends not undercutting the mica, but make certain that no brass particles are left on the insulation strips between the segments. If you do not have a lathe available, the armature can be taken to an automotive machine shop to have the work done. There are also some special tools made for turning commutators and undercutting mica. They take the place of a lathe and do an excellent job if used correctly.

STARTER BRUSH REPLACEMENT

Brushes should be replaced if they are not making good contact with the commutator or whenever they have worn down to a length of 5/16-in. Always install a complete set at one time to equalize wear.

After removing the brushes from their holders and the end plate from the starter, the armature can be taken out. The old brushes may then be removed. This calls for some work with a soldering iron, since the four new brushes must be soldered to the field and ground wires in place of the old ones. On Autolite starters, the two ground brushes sometimes do not require unsoldering since the new brushes come with the wire already attached. These can simply be screwed onto the terminal. All carbon, grease and dirt should be cleaned from the end plate, and if the insulation barrier between the field brush holders and the end plate is cracked or broken, the entire end plate should be replaced.

The new brushes may now be soldered onto the correct wires. Any flux that remains from the soldering job should be cleaned off with baking soda and water.

How to insert the brushes into the starter will be obvious after you have made a couple of false starts. In general, starters without slots in the frame must have the brushes in place before the armature is inserted. When the starter has slots, then the end plate and armature are installed, and the brushes put into their holders through the slots. The brushes must pivot freely or slide freely, whichever method is used, so that they will have good, firm contact with the commutator.

The ground wires should be reconnected in their original places before the end plate is completely in place. Be careful not to pinch the brush leads between the end plate and the frame. Also, if there is not a dowel or notch to locate the correct position of the plate on the frame, mark the plate and frame when taking the starter apart so that they can be reassembled in their proper relationship. Once the starter ends are in place, the two through-bolts can be inserted and tightened.

If electrical trouble exists within the windings of the armature or field coils, the repair is definitely not one to be attempted at home. In fact, having the starter rewound by an automotive electrician would be more expensive than simply replacing the starter with a rebuilt one. New armatures and field coils are available from new car dealers' parts departments, but the cost is sometimes equal to that of a rebuilt starter at an independent parts store. Therefore, the main value of the following tests to home mechanics is (1) to determine if the starter really needs replacement, (2) to pinpoint the trouble so that you can replace the starter's armature or frame with a used part, and (3) to test used components to make sure that they are serviceable.

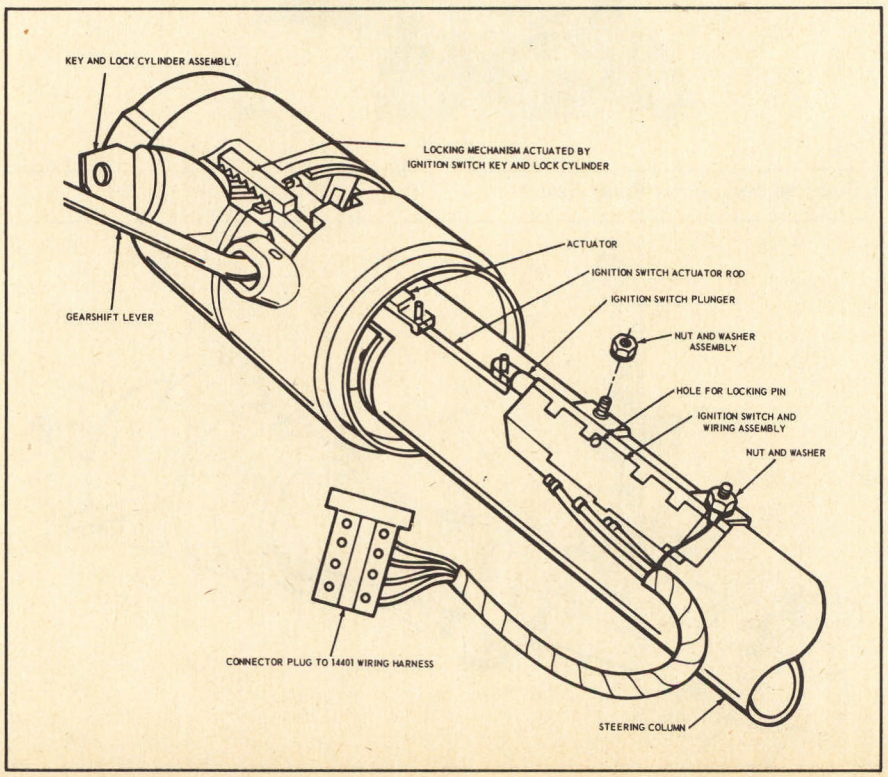
Tests for grounded circuits in field windings and armatures can be made with a voltmeter and the car's battery, a self-powered ohmmeter, or a simple battery-operated test light. By connecting one test lead to the shaft and touching the other to the commutator, you can quickly detect grounded circuits in an armature. If any current passes through to the shaft, as indicated by a voltmeter reading or by the test lamp lighting, the armature is defective. The trouble was probably caused by failure of the winding insulation. The only practical repair is to replace the armature—if this is economically possible. Otherwise install a rebuilt starter. A device known as a "growler" is sometimes used to test armatures for shorted windings.

An open circuit in the armature can often be detected by examining the commutator for signs of burning. The burned place is caused by an electrical arc that is formed each time the commutator segment connected to the open-circuit winding passes under a brush rubbing surface.

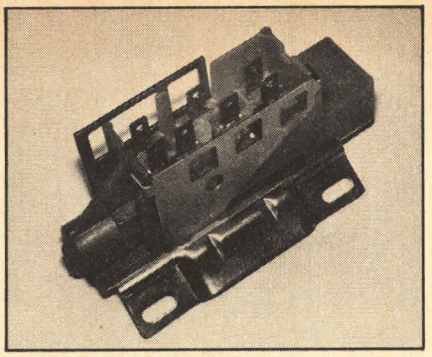
The field coils can also be tested for grounded circuits using a voltmeter or test light. The same hookup is used as in testing the armature. The field brushes *must not* be in contact with the starter frame during the test. One lead from the battery is connected to the starter terminal, and the lead from the voltmeter or test lamp is touched to the starter frame. If the voltmeter shows a reading or if the test light comes on, it is an indication that the field windings are grounded.

Open circuits can be tested by attaching the battery lead to the starter terminal, and the voltmeter or test lamp lead to each of the field brushes in turn. Do not test the ground brush. If one or all of the brushes fails to light the test lamp or produce a full voltmeter reading, the field coils have an open circuit. If an open circuit is located, the wire leading from the brush to the coil should be checked for breaks. If the open spot is in the windings themselves, you will either have to get the field coils replaced by an automotive electrician or turn the starter in on a replacement.

Summing it up, let's remember that internal starter troubles are generally as rare as free samples at a U.S. mint. However, some makes do have starting motor problems because their starters are too small for the job they have to do. The trouble usually shows up as a drag-



1. Ford Ignition Switch



2. Chevrolet Ignition Switch

1. Many late-model cars with locking steering columns have their ignition switch low on the steering column, as on this Ford.

2. A Chevrolet ignition switch, which is typical of GM cars. The steering must be lowered to get the switch off the column.

3. Major pieces shown in this view of a disassembled Ford starter (late model) are, top: commutator and starter drive and long bolts; center: pole shoe cover, shifter forks, and starter drive housing; bottom row, from left: starter cover band and end plate assembly.

ging armature from worn bearings or bushings. Open-circuited or shorted armatures can result, too.

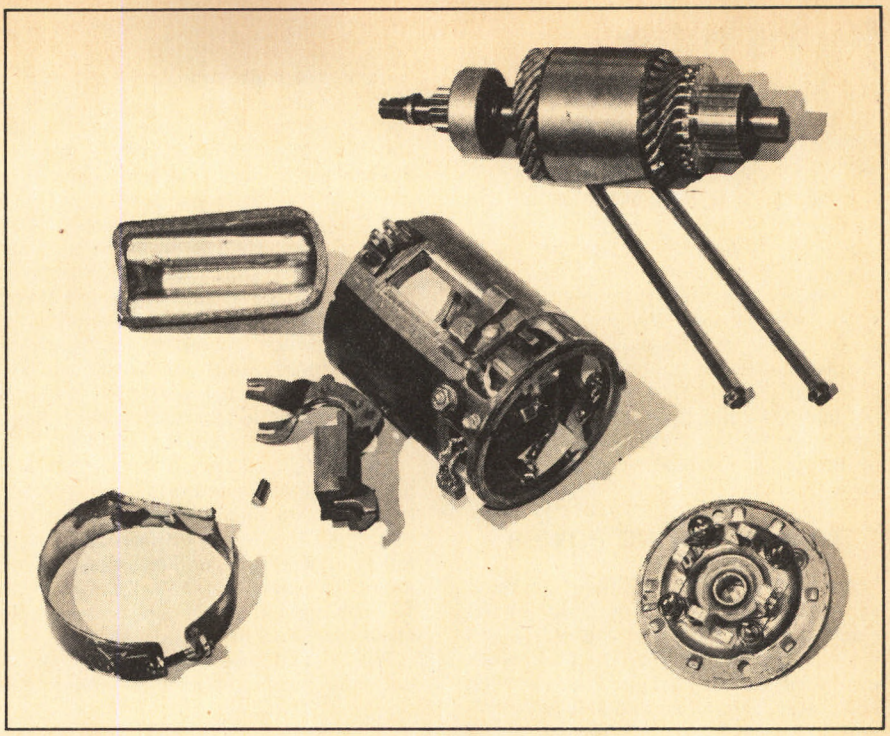
Many short trips cause a starter to be used more than normally. On long trips a starter might be used only once a day. The type of driving has a lot to do with how long the starting system will be trouble-free, just like everything else on a car.

Before you perform any exploratory surgery on the starter motor itself, be very certain that the other parts of the starting system have been thoroughly tested and inspected. Furthermore, many starter troubles have been licked just by taking the starter apart and cleaning it. This is something to remember when installing a used starter. Clean it before you hang it on the engine and you're much more likely to be satisfied with your "bargain" replacement.

HARD-STARTING CAUSES

Sometimes the starting system gets blamed for trouble that isn't really its fault. More than one amateur mechanic has ended up with a dismantled starter in his lap while the real trouble lurked in the engine room. While these things are not, strictly speaking, starting system troubles, we'll list them here so that you'll at least be warned and on the lookout should your starter fail to turn the engine over some bright and sunny day.

1) Hydrostatic lock occurs when a cylinder becomes filled with water. (Or, in rare instances, gasoline or oil.) Liquids will not compress—that's what makes hydraulic brakes possible—and if there is a greater volume of water in a cylinder on its compression stroke than the combustion chamber can hold, the engine will not turn. The usual cause is a leaking head gasket or a cracked cylinder head.



3. Late Ford Starter

2) Oil rundown is a condition that usually strikes the turnpike traveler. After bombing along at 75 or 80 mph for 3 or 4 hrs., the oil in an engine can get pretty thin and watery—especially if it is some kind of 30¢-per-quart "cheapie," or hasn't been changed since the election of '68. The trouble starts when you pull into a service station for gas. After your tank has been filled and the windshield scrubbed you prepare to continue on your happy way, but the starter will hardly turn the engine! It sounds as though the battery has run down—a highly improbable condition on a long high-speed trip. The real trouble is that your hot, thin oil has run right off the cylinder walls, leaving them as dry and unlubricated as scorched sandpaper.

Don't let some "sharpie" sell you a battery—save your dough for an oil change. To get started, just take off the air cleaner and pour some SAE 10 engine oil into the carb intake while someone else runs the starter. The cranking speed will soon increase and the engine should fire right up.

3) Heavy oil can place a tremendous load on the starter in cold weather. If you still have SAE 30 in the engine when the first cold blast of winter arrives, don't blame your misery on the starting system. With the temperature at 10° or 15° below the freezing point, even the best starting system probably won't budge an engine that's been sitting out all night with a crankcase full of summer-grade oil.

4) Carbon buildup in the combustion chambers can both increase the effective compression ratio of an engine and, when heated to incandescence by a high-speed run, convert your engine into a "diesel." Carbon particles may remain glowing coals for many minutes after the engine is switched off. When you try to restart the engine, the increased compression and the glowing carbon cause the fuel to ignite before the spark plugs fire. Since ignition is taking place long before the pistons near the top of their stroke, the engine tries to run backward, fighting the starter. Lots of people have spent money on their starting system trying to cure this before finally pulling off the heads to get rid of all that carbon.

Excessive initial spark advance or a defective distributor can cause symptoms similar to those produced by carbon buildup; however, this will also cause trouble when the engine is cold.

5) Mechanical interference is another possible source of starting trouble. It's usually the result of improperly done tune-up or repair work—such as installing the camshaft 180° from its correct position.

If you have been working on the car, and it then refuses to start, check on your own work before condemning the starter.

6) Antifreeze lockup will call a halt to engine cranking just as quickly as a mechanical lockup. Antifreeze is not a lubricant. When it seeps through a head gasket and gets on the cylinder walls, the pistons and cylinders like each other so well that they are inseparable. This problem usually shows up on the first attempt to start in the morning, after the antifreeze has had all night to do its seeping. The test is to drain the cooling system and fill it with water only. Usually, the cranking problem will go away. You should then put a good sealer in the cooling system and then just refill it with antifreeze.

In some cases the antifreeze contaminates the engine so badly that merely draining the cooling system will not help. In that unhappy situation you have to use a compound known as Butyl Cellosolve in the oil. It will pick up the antifreeze from the engine, if you follow directions on the package.

7) Piston seizure, similar to oil rundown, can also cause a no-crank condition. If the cooling system is partially

Starting System

clogged around the cylinders, local hot spots develop which expand the cylinders unevenly. If magnified, the cylinder surface might look like a plowed field. The hillocks grab hold of the piston and won't let it move in the cylinder. It will happen every time the engine gets up to operating temperature. Let it cool, and the engine will start normally. A thorough cooling system cleaning will get rid of this problem. We have seen some people cure it by putting in high-powered starters and heavy-duty batteries, but that's like putting a cork in your tailpipe to stop exhaust smoke. It may cover up the problem temporarily, but it won't cure it.

MORE STARTING POWER

The stock starting systems on most cars were designed to do their job on stock engines. Some of the last 6-volt systems were hardly up to their work even then! As soon as you start boosting compression ratios and fiddling with ignition and valve timing, you're making the starting system's life a little more fraught with drudgery.

There are no "hopped-up" starter motors marketed at the local speed shop, but there is something almost as good waiting at the nearest parts store or wrecking yard; namely a truck starter. Most of the standard blocks used in passenger cars also get punched out and draped with different accessories for use in trucks. In most cases the heavy-duty "commercial" starters will bolt right onto them. You can usually find out "what'll fit what" by checking the exploded view drawings in the dealer's parts catalog.

Commercial starters have a greater current demand than those found on standard cars and, therefore, depend on a more powerful battery. This is something that should be considered anyway when planning a starting system for your "rod."

Cars that were originally built with a 6-volt electrical system can have their starter changed to a more powerful 12-volt number without completely rewiring the car and throwing out all 6-volt instruments and accessories. The answer is a "6-12" starter-electrical system. The heart of the system is an automatic voltage converter switch such as the Orpin unit. All you do is add a second 6-volt battery and wire the batteries and starter into the switch according to the directions. This system will automatically shoot 12 volts to the starter for cranking the engine without increasing the voltage to the rest of the electrical system.

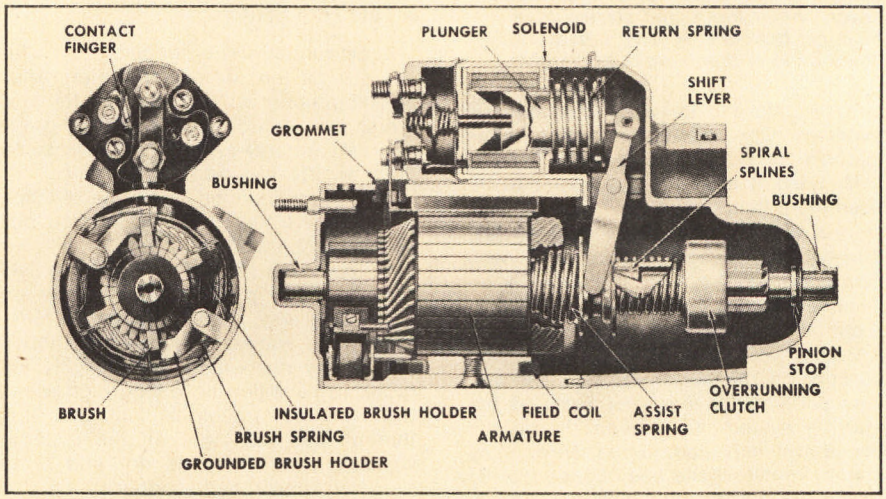
There are also several conversion kits that permit using entire 12-volt engines in 6-volt cars and 6-volt engines in 12-volt cars. The 6-volt starters can be fitted to engines that originally had 12-volt jobs, but converting a 6-volt system to 12 volts will get you much more reliable starts than a 12-to-6 starter swap.

This should give you a good idea of just what takes place in a modern-day automotive starting system. Starting systems have come a long way since the day of the crank, but they still aren't so overly complicated that the home mechanic can't service them. This is especially true in preventive maintenance, which includes battery terminal cleaning and checkups, tightening connections and inspection of wiring. This is all part of good-car-care that will result in dependable transportation for you—from the very start.

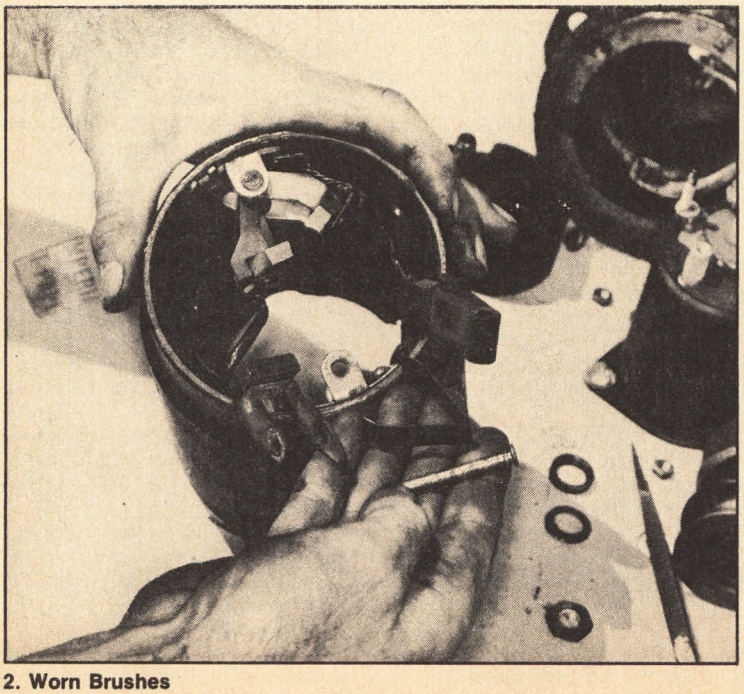
1. Delco-Remy starters have changed very little over the years. Recent models have had two distinguishing features added to them: non-reversible solenoid contacts and a fully enclosed drive housing.

2. Worn brushes can cause a no-start problem. Pin retains entire assembly, which, when removed, allows brushes to be replaced.

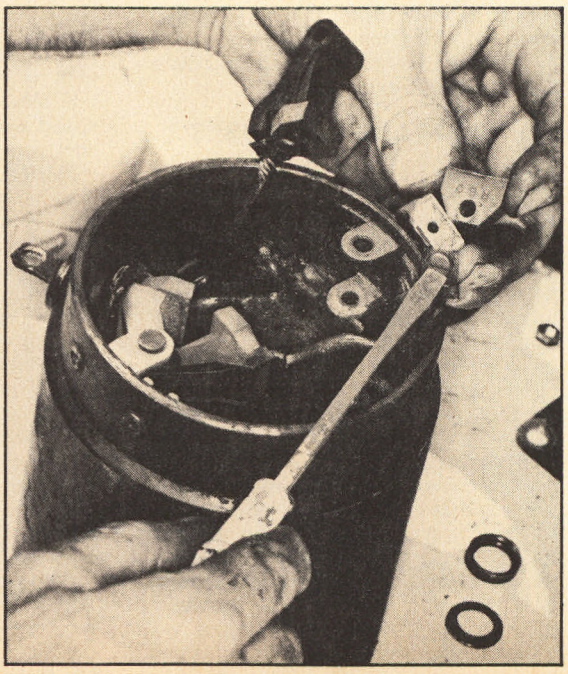
3. Brushes are attached to holders with small screws. No solder needed. Disassemble one pair of brushes at a time. Use other pair as an example.



1. Cutaway of Delco-Remy Starter

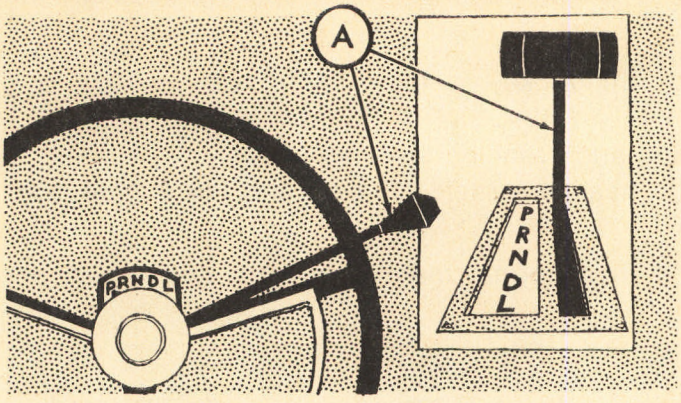


2. Worn Brushes



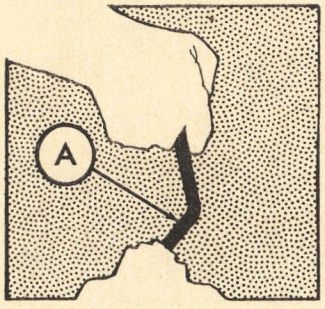
3. Brush Holders

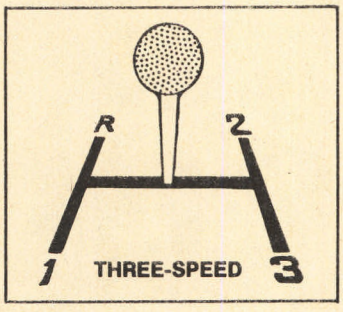
TROUBLESHOOTING THE STARTING SYSTEM

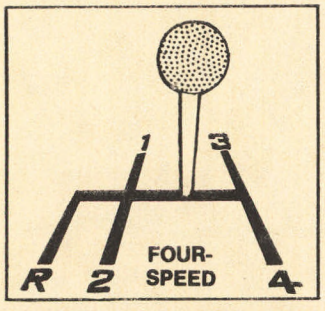


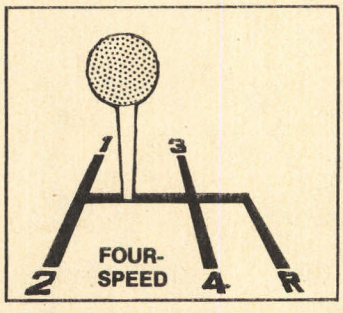
IS THE AUTOMATIC TRANSMISSION IN "P" or "N"?

Cars equipped with automatic transmissions will not start unless the transmission shift selector lever (A) has been placed in the PARK (P) or NEUTRAL (N) position. There is a switch called the neutral safety switch that is part of the starting circuit. This switch prevents the starter from working unless the shift lever is in one of these two positions. This is a safety feature, designed to keep the car from jumping forward (if left in gear) when the starter is used.







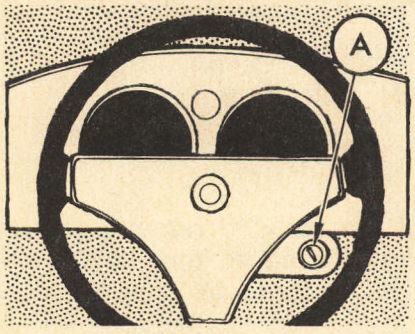


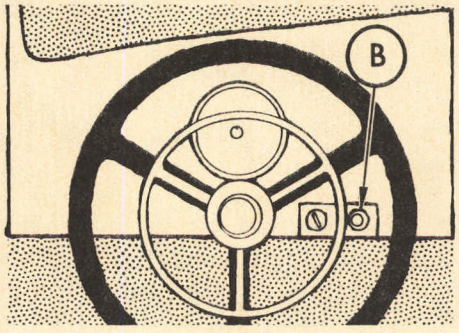
IS THE STANDARD SHIFT TRANSMISSION IN NEUTRAL?

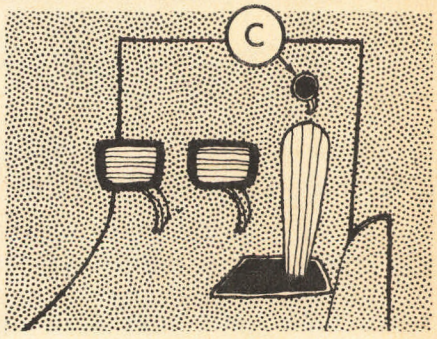
Cars and trucks equipped with a standard (manual) shift transmission should have the shift lever (A) placed in the neutral position before attempting to start the engine. Placing the transmission in neutral will prevent forward motion of the car when the starter is operated.

On standard transmission cars manufactured after 1970, the clutch pedal must be depressed before the starter will function. There is a switch much like the neutral safety switch on automatic transmission-equipped cars to prevent the starter from working unless the engine is separated from the driveline by depressing the clutch pedal.

CAUTION: ALWAYS ENGAGE THE EMERGENCY BRAKE BEFORE STARTING THE ENGINE. THIS PREVENTS THE CAR FROM ROLLING WHEN THE TRANSMISSION IS IN NEUTRAL.







IS THE IGNITION ON?

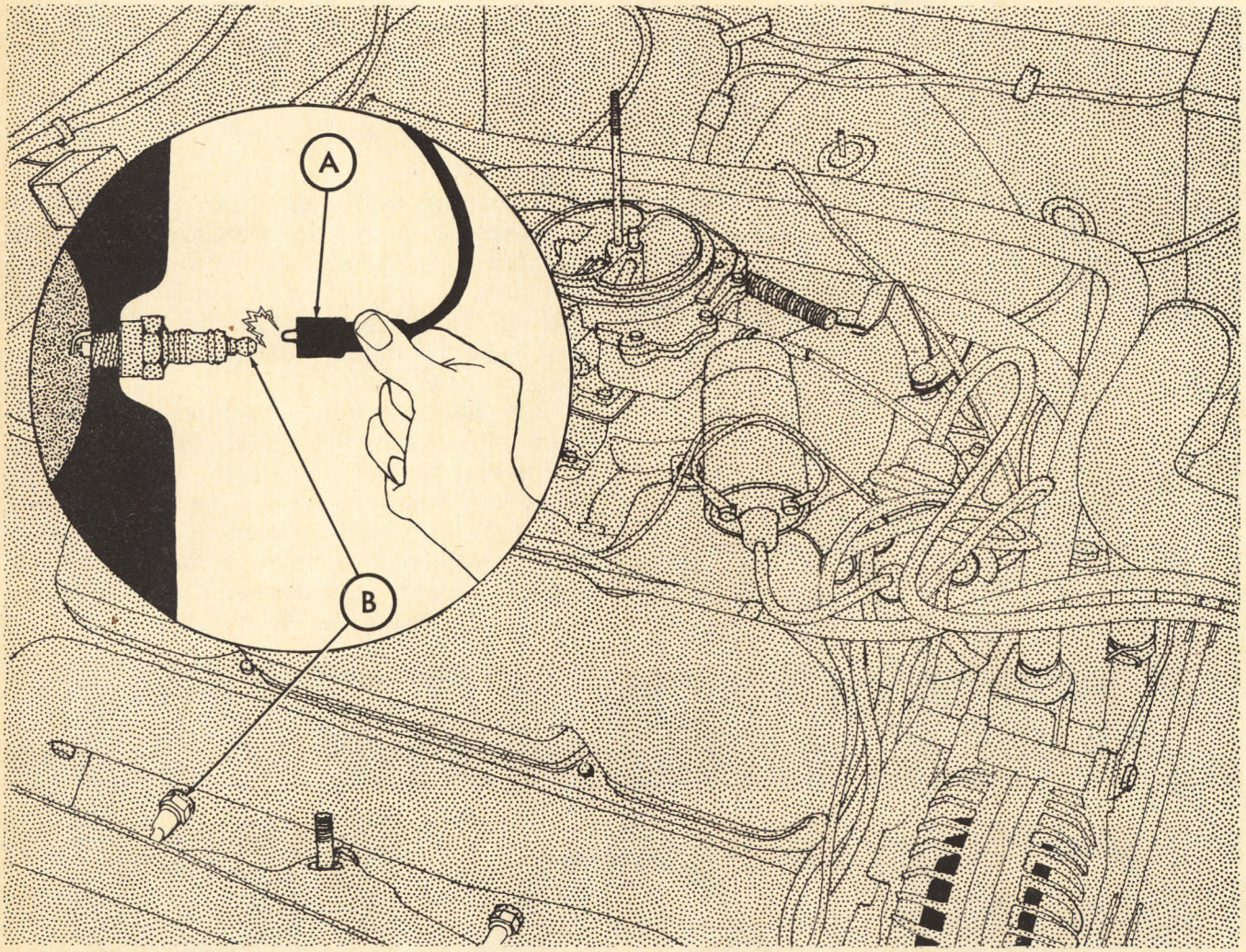
While most modern automobiles are equipped with a key-lock type of ignition switch (A), some older cars and many light trucks have a separate starter switch (B, C). This is usually located on the floorboard near the gas pedal or on the dashboard. With a modern key-lock ignition switch, the starter is engaged by turning the key to the START position. When the engine has started, the spring-loaded switch returns to the ON position.

With older cars that have the separate starter switch, the ignition key is turned to the ON position and the starter switch is depressed until the engine has started. Then the switch is released.

TROUBLESHOOTING THE STARTING SYSTEM

STARTING SYSTEM CHECK

- Test engine cranking system by turning ignition key to the START position. (On cars equipped with separate starter switches, turn key to ON and depress the starter.)
- Listen for the sound of the starter engaging and cranking the engine over.
- If nothing happens or the only sound you hear is a rapid clicking and the engine does not crank over, troubleshoot the starting system.
- If the starter is cranking the engine over in a normal manner but the engine will not start, continue to the ignition check below.

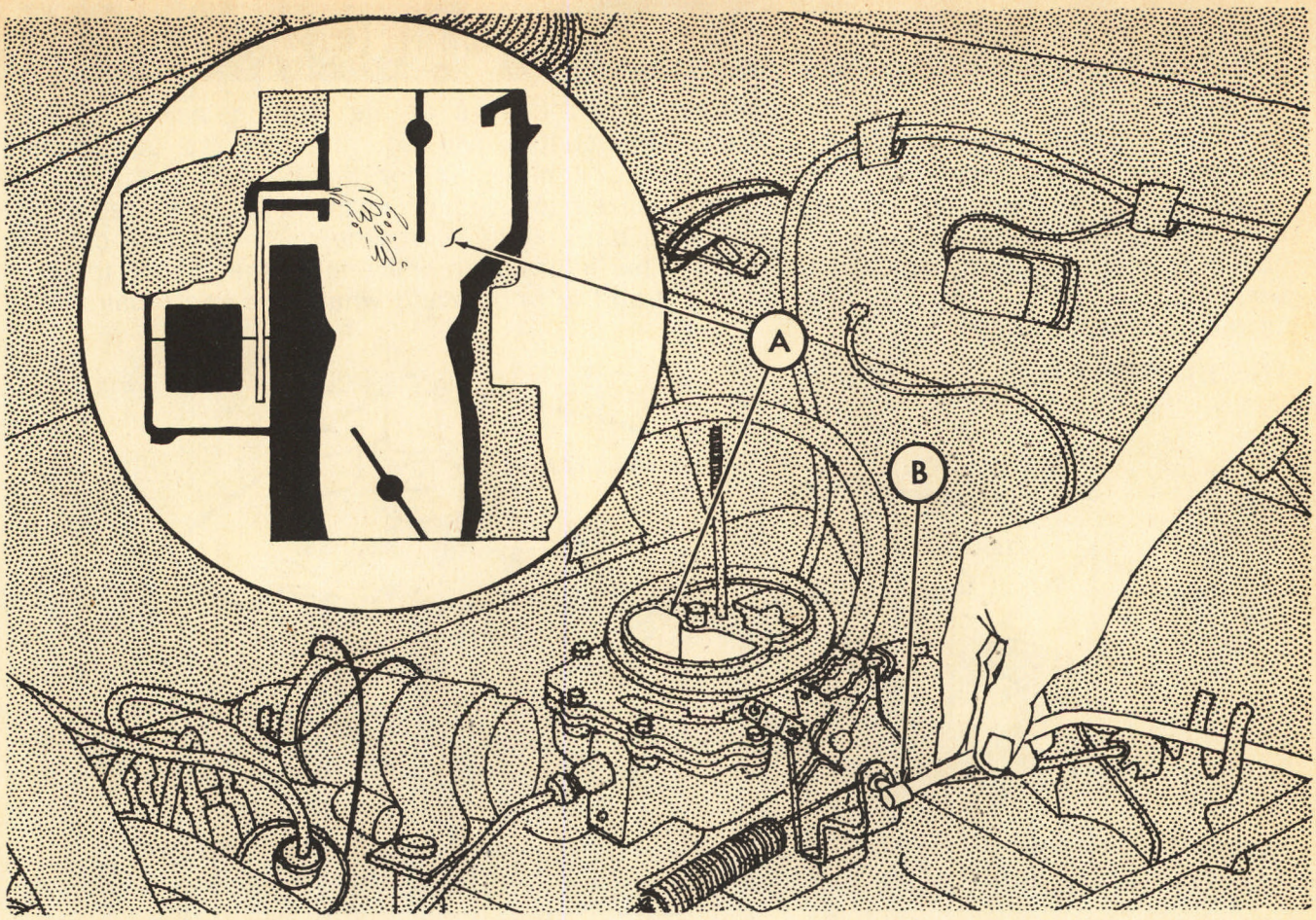


IGNITION SYSTEM CHECK

- To test the ignition system for operation, open the hood of the car and remove one of the spark plug wires (A) from a spark plug (B). Hold the spark plug lead approximately ¼-inch from the tip of the spark plug and crank the engine over. This usually requires two people, one to hold the spark plug lead, another to operate the starter. (Use a paper clip for this check.)

WARNING: BE SURE TO HOLD THE SPARK PLUG BY THE INSULATED COVERING. HOLDING THE SPARK PLUG LEAD BY THE METAL TIP CAN GIVE YOU AN ELECTRIC SHOCK.

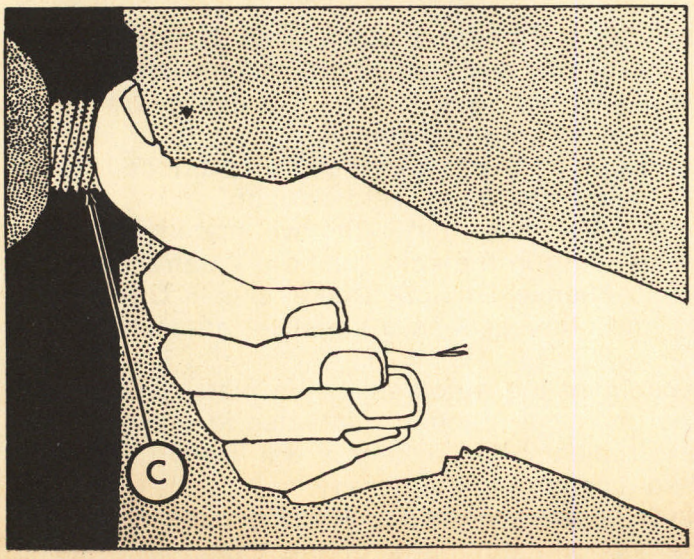
- If there is no spark or only a very weak spark when the engine is cranked over, troubleshoot the ignition system.
- If there is a strong spark when the starter is operated but the engine will not fire, proceed to the fuel system check on the next page.



FUEL SYSTEM CHECK

- Remove the air cleaner or air cleaner cover to gain access to the top of the carburetor.
- Grasp the throttle linkage (B) and open and close the throttle several times while watching for a small stream of fuel in the bore (A) (opening) of the carburetor. Opening the throttle means pulling or pushing the linkage so that it operates in the same way it would if the gas pedal were being pushed.
- If you cannot see any fuel squirting into the carburetor bore, troubleshoot the fuel system.
- If fuel can be seen squirting into the carburetor but the engine will not start, go to the engine compression check below.

ENGINE COMPRESSION CHECK

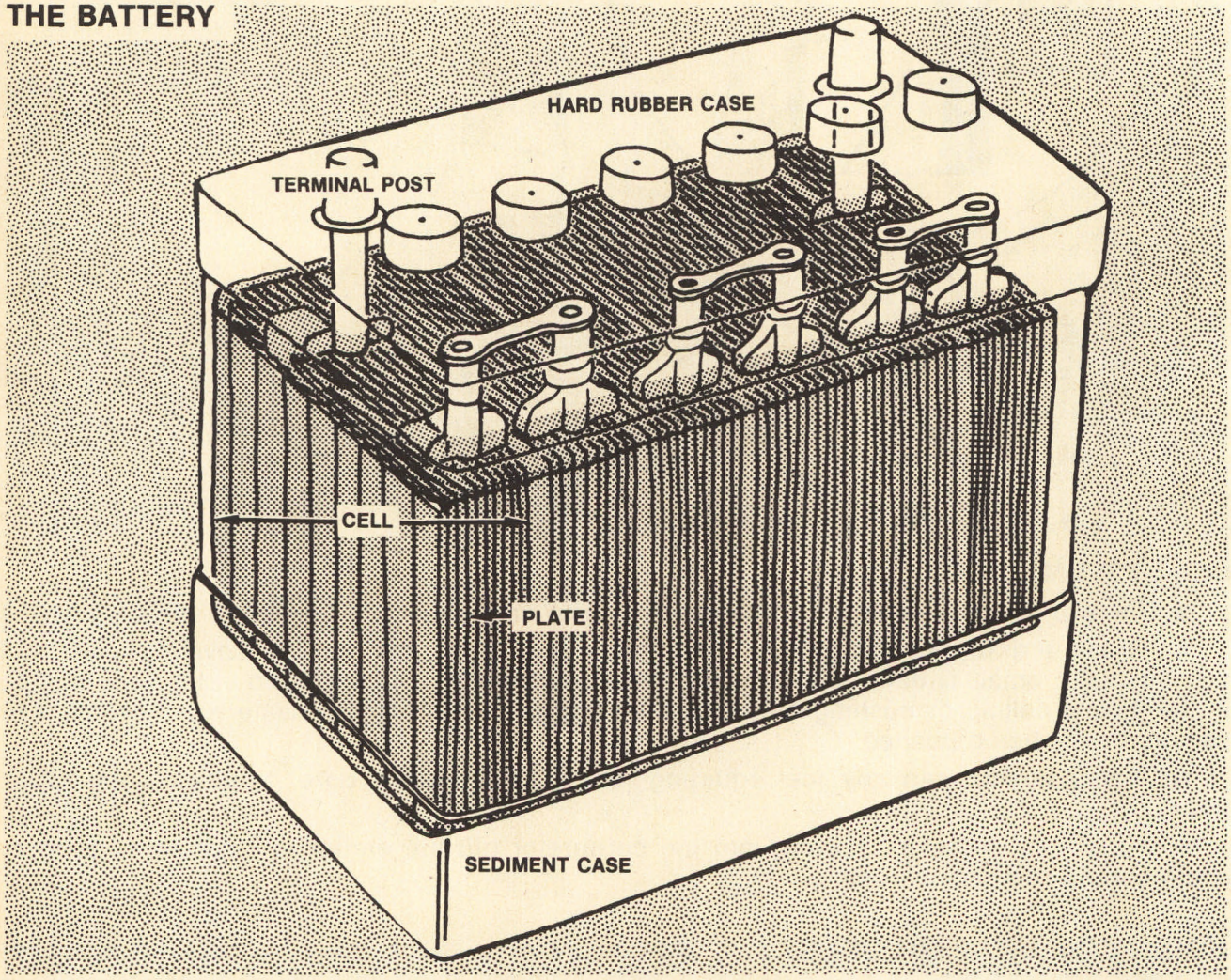


- Compression is the pressure built up inside the cylinder when the piston moves up on the compression stroke. To check this quickly, remove one of the spark plugs, place your finger over the spark plug hole (C) and crank the engine over with the starter. Note: This also usually requires two people, one to operate the starter, the other to check compression.
- If the compression is good, the rising pressure in the cylinder will force your finger off the hole. If you have gotten this far without finding any problems in other systems, check all cylinders for lack of compression.
- If there is a lack of compression in any or all cylinders, it indicates a serious internal problem. Proceed to the ENGINE COMPRESSION CHECKS on page 448.

TROUBLESHOOTING THE STARTING SYSTEM

In this chapter we will go into more detailed checks of the starting system of the automobile. Some of the checks described in this chapter will require simple test equipment, but the use of such equipment will be held to a minimum for the benefit of the home troubleshooter who may not have such specialized tools at his disposal. Checks requiring very specialized testing tools will be mentioned, but only to inform the reader of what can be done to confirm or deny specific problems. This information will enable the reader to take suspected bad parts to a shop for a check-out and to understand what tests and repairs may be required at the shop.

THE BATTERY



The battery used in automobiles is known as a storage battery. This is not entirely correct. The battery produces its electrical energy by electrochemical action without an external source of electrical energy. The battery does not "store" electrical energy; rather it is simply ready to produce electricity from this chemical source instantly.

Automobile batteries are of the lead-acid type. In them, electricity is produced by a chemical reaction between two types of material suspended in an acid solution.

The battery is an acid-proof container filled with this acid. The two materials which produce the electrochemical reaction are in plates hung in the acid solution. When these two dissimilar materials are acted upon by the acid, a chemical reaction takes place. One set of plates acts as a positive terminal for electricity; the other acts as a negative terminal. A flow of electricity takes place inside the battery.

As this current is used in the electrical system of the automobile, the plates are slowly altered by the repeated chemical reaction. This chemical reaction continues to manufacture more electricity, but unless something is done to replenish the battery, it will finally discharge all the available electrical potential. This is called discharging the battery.

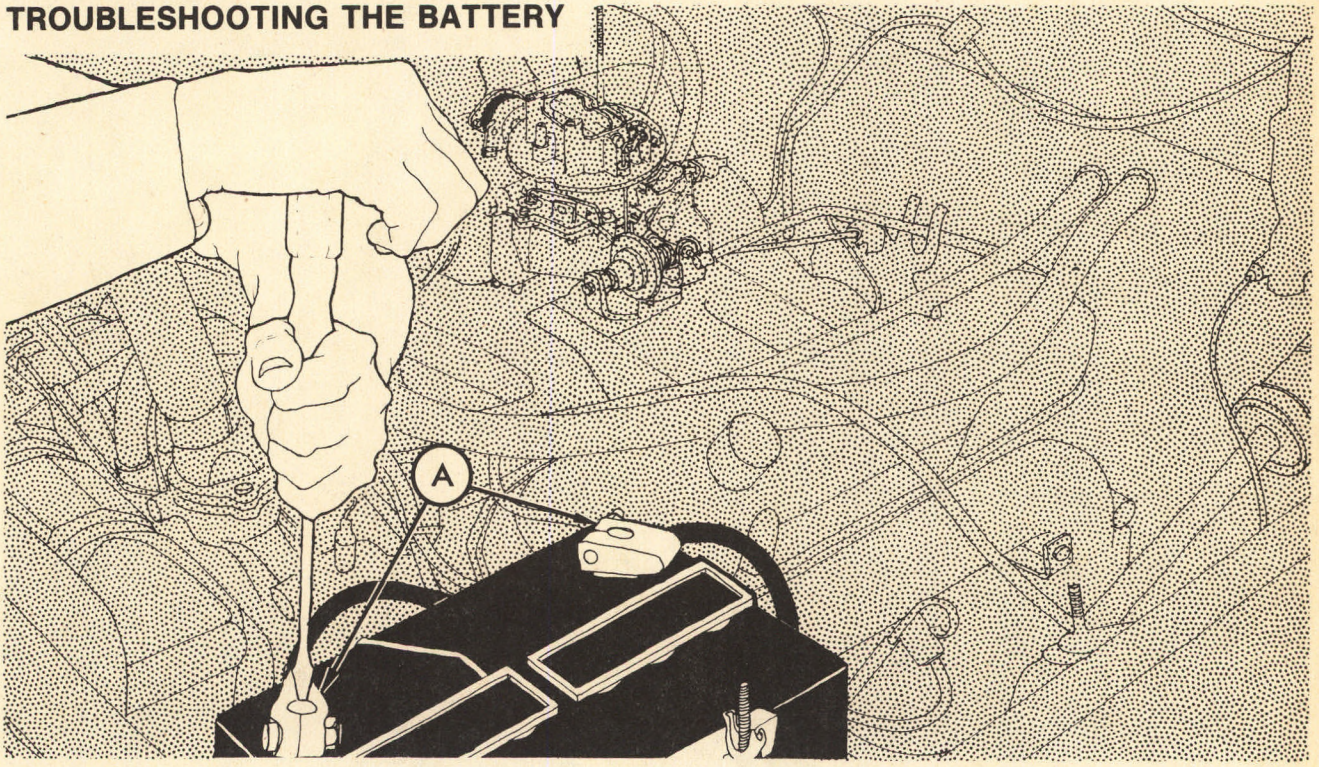
Once the available supply of electricity falls below a certain point, the battery can no longer supply the force necessary to operate the different parts of the electrical system.

(Information on how the battery is recharged while in use will be found in the chapter on charging systems.) The process of recharging does not add electrical energy to the battery (remember, the battery does not "store" electricity); recharging only reverses the effect of the chemical process by reversing the current flow and building up the plates so that the battery can again provide a full flow of electrical current.

In actual practice, the automobile battery is made up of a number of smaller batteries called cells. These cells are encased in the acid-proof outer container and are connected in series to provide the correct electrical potential. Each has its own supply of acid, and each cell is actually a complete battery by itself.

While the battery is the most important part of the ignition and charging systems as well as supplying electricity for all the electrical accessories, it is also the most important part of the starting system.

TROUBLESHOOTING THE BATTERY



If the battery is to operate correctly, it must be in good internal condition (not discharged or damaged). Also, the connections (A) which feed current from the battery to the other parts of the electrical system and back again must be in good condition. The electrolyte (battery fluid) should be up to the full marks on the inside of the filler holes.

WARNING: THE WHITE MATERIAL ON A CORRODED BATTERY POST OR CONNECTOR IS ACID. DO NOT GET IT ON YOUR SKIN OR IN YOUR EYES. IT CAN ALSO DAMAGE CLOTHING. IF YOU ACCIDENTALLY GET ACID ON YOUR SKIN OR IN YOUR EYES, WASH IMMEDIATELY WITH CLEAR WATER. SEE A DOCTOR IF BURNING SENSATION PERSISTS.

One quick method of checking electrical connections on the battery for a good connection is to force something between the metal of the post and the metal of the connector. (Some batteries don't have the posts on the top; they are located on the side and use a screw type of connector.) The metal used for battery connections is mostly lead and is quite soft. A screwdriver jammed into the area between the battery post and the connection often creates a good connection if corrosion or dirt is the cause of the problem.

If, after this is done, the battery seems to provide more starting force (that is, if the starter cranks better or the headlights are brighter), the problem is most likely in the connections. Loosen the connections with a wrench and examine them carefully for signs of corrosion. This is usually a whitish buildup of material around the battery post and connector. It can also be just a fine film that is not easy to see, but if corrosion is present, the surface of the post and the inside of the connector will be dull instead of shiny.

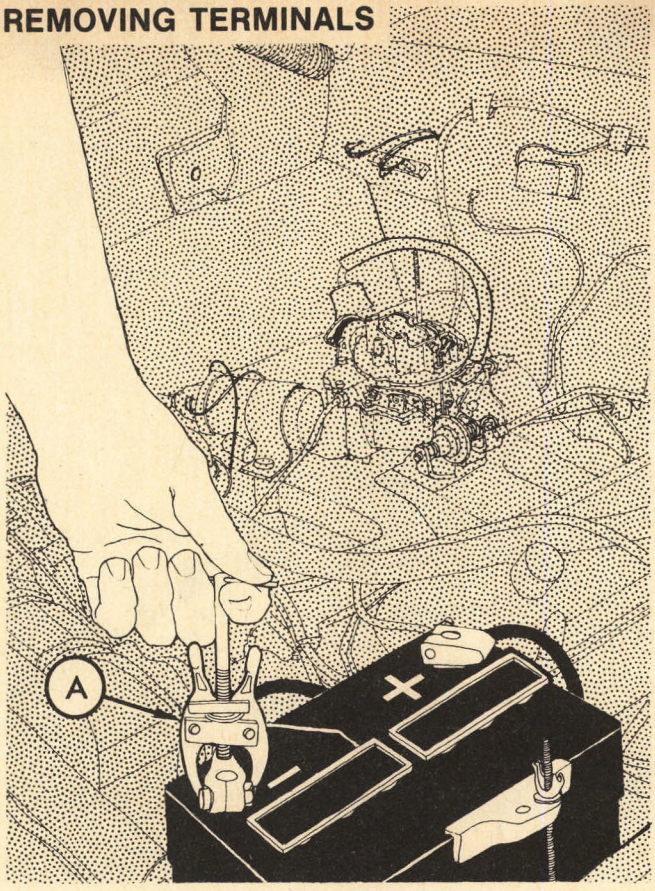
TROUBLESHOOTING THE STARTING SYSTEM

NEUTRALIZING ACID

CAUTION: DO NOT LET ANY OF THE BAKING SODA GET INTO THE BATTERY. IT CAN NEUTRALIZE THE ACID IN THE BATTERY AND RUIN IT.

The acid buildup on battery posts and connectors can be neutralized with a solution of baking soda and water. Sprinkle dry baking soda on the top of the battery and connections, making sure that the filler caps for the acid are on securely. Add a small amount of water to the baking soda. If it starts to bubble and you can hear a fizzing sound, there is battery acid present on the surface of the battery. The baking soda will help to neutralize it, and it can be removed with a stiff-bristle brush. Several applications of baking soda and water may be necessary to completely remove all corrosion buildup from the surface of the battery.

REMOVING TERMINALS

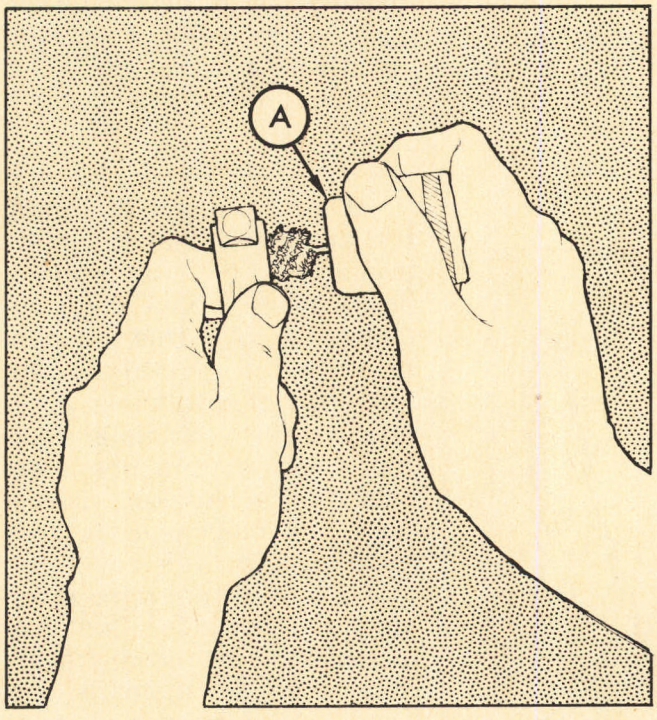


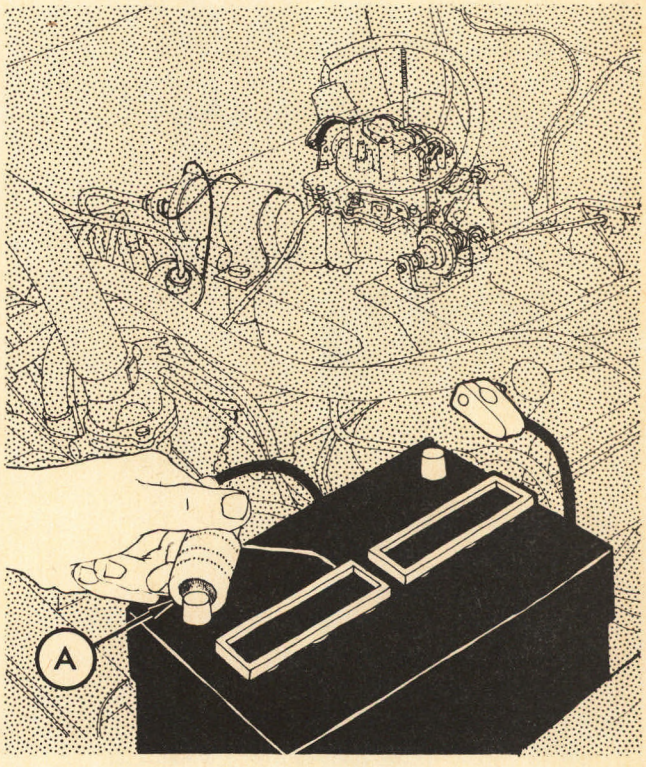
CAUTION: WHEN REMOVING AND REINSTALLING BATTERY CABLES, ALWAYS REMOVE THE NEGATIVE (-) CABLE FIRST. THIS REMOVES THE BATTERY FROM THE CIRCUIT AND PREVENTS ACCIDENTAL SHOCK OR ARCING. WHEN REINSTALLING THE CABLES, ALWAYS INSTALL THE POSITIVE (+) CABLE FIRST AND THE NEGATIVE CABLE LAST.

Post-type terminals should never be forced off the post. Use a twisting action to loosen the connector. If it is too tight to remove in this manner, use a battery cable puller (A). Too much force applied to the post can damage the post or loosen it in the battery case material.

When replacing the connector on the post after cleaning, it helps to use a socket to drive the terminal firmly onto the post before tightening the nut with a wrench. Be sure the socket is larger in diameter than the post and apply force only to the connector. Striking the top of the post may drive it down into the soft battery case and damage it.

CLEANING TERMINALS

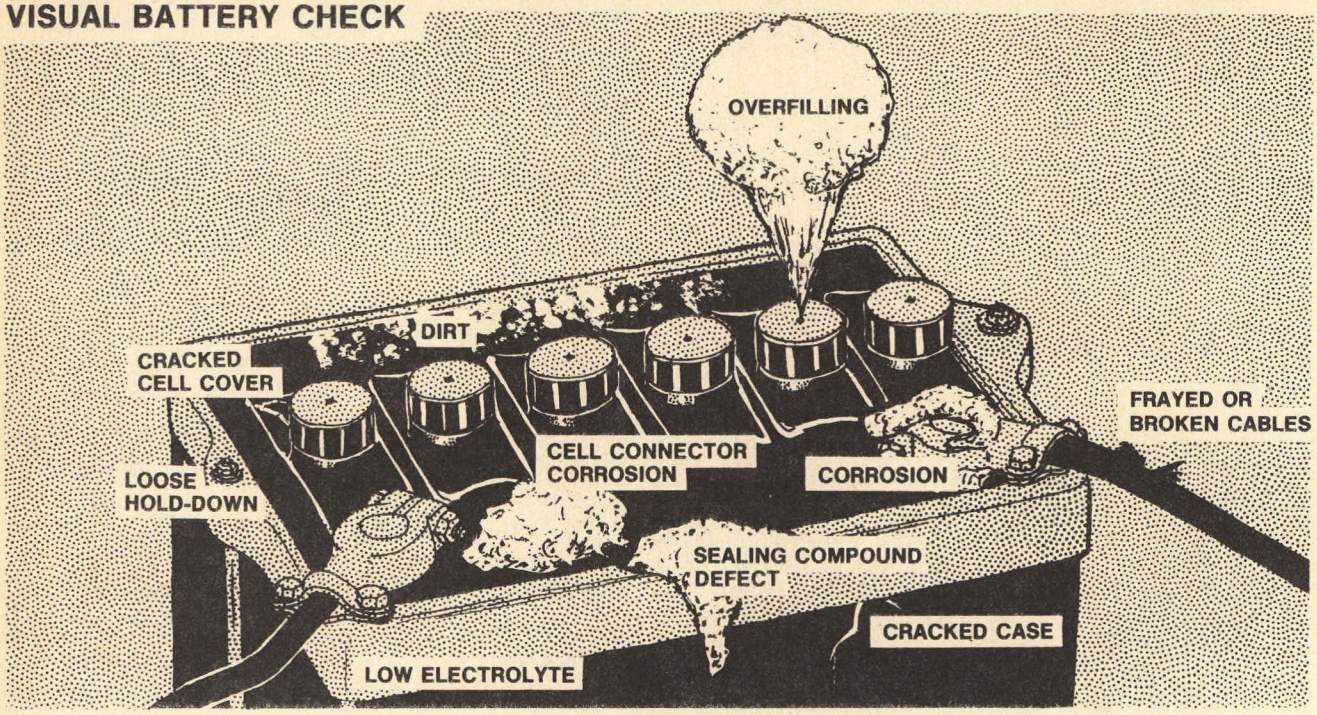




The battery posts or terminals themselves can be cleaned of hardened corrosion and restored to their normal condition by the use of a wire brush and post cleaner (A). If a post cleaner and wire brush are not available, sandpaper, steel wool or even a knife blade can be used to clean the post and inside the connector. All residue or corrosion should be cleaned from the inside of the connector where it contacts the post. The post itself should be cleaned in the same manner. Properly cleaned, the post and connector will have good electrical conducting properties. A light film of grease or paint over the connection after it is tightened in place will help prevent the buildup of new corrosion.

TROUBLESHOOTING THE STARTING SYSTEM

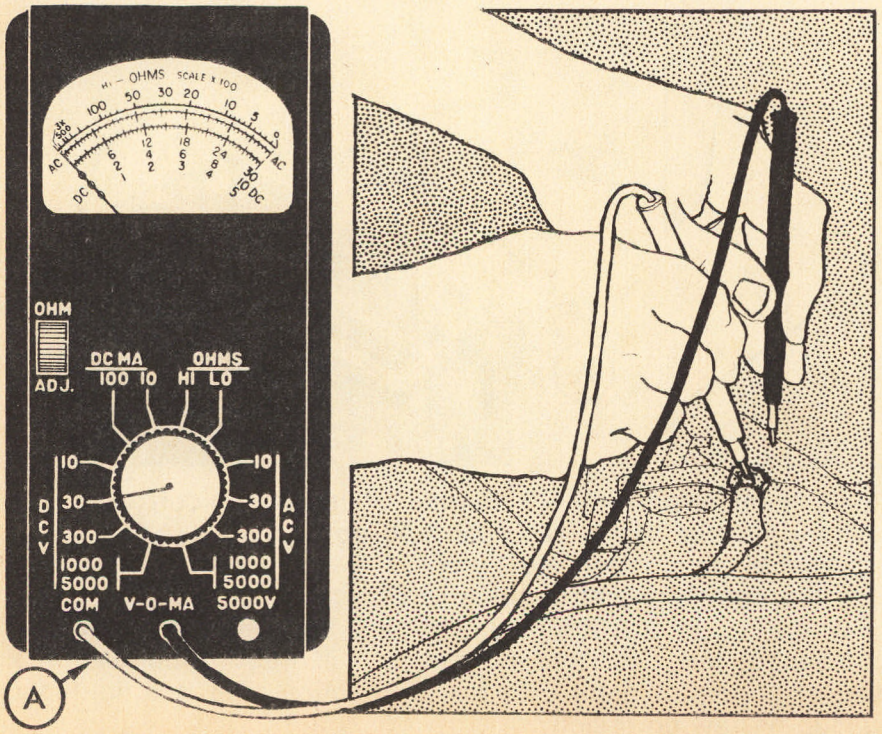
VISUAL BATTERY CHECK



Check the battery carefully for visual signs of battery problems. If the battery still shows no signs of life after the cables and posts have been examined and cleaned (if necessary), remove the battery and have it tested by a mechanic with the proper test equipment

The mechanic will test the battery in two ways. First he will make a test to determine the battery's state of charge (how much electricity it has left) by using a battery tester. The tester measures the voltage of the battery. He will then test the battery acid with a hydrometer. This tester measures the acid content of the fluid in the battery and gives the mechanic much valuable information about the battery's condition.

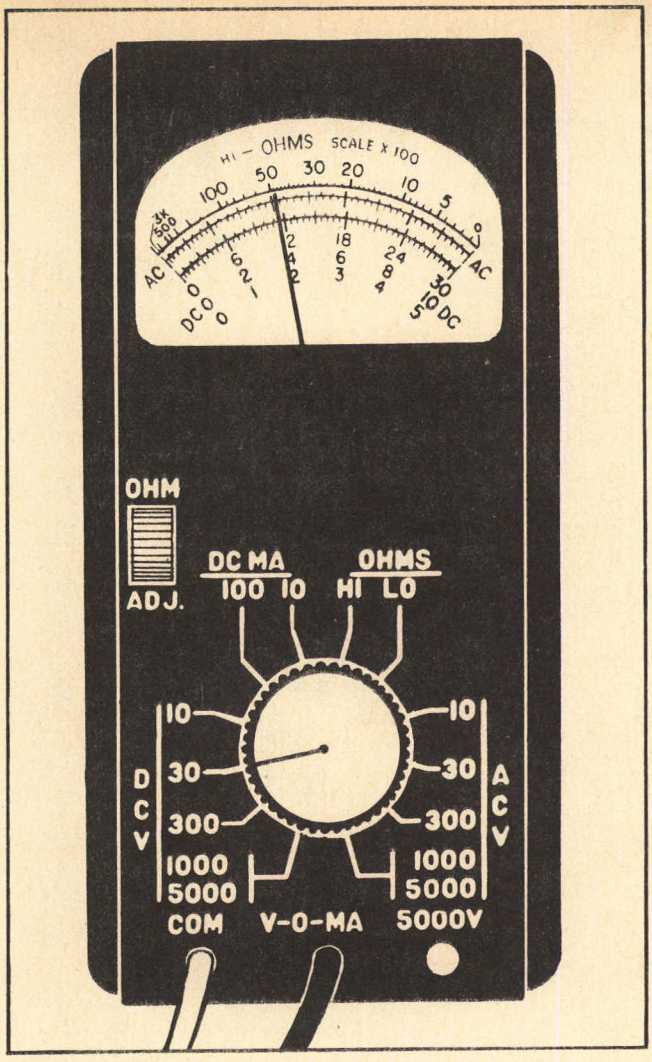
USING THE VOLT-OHM METER



One item of electrical test equipment that should be available to the troubleshooter is the volt-ohm meter or multimeter (A). This inexpensive device combines the functions of a voltmeter (voltage checker), ammeter (current checker) and ohmmeter (resistance checker) in one unit. The multimeter is easy to use and will save you much time when working on electrical systems. Complete instructions are usually available when the meter is purchased, or you can find instructions in Petersen's AUTOMOTIVE TUNE-UP & TEST EQUIPMENT.

With this meter, you can perform a further check of battery condition with the battery still in the car.

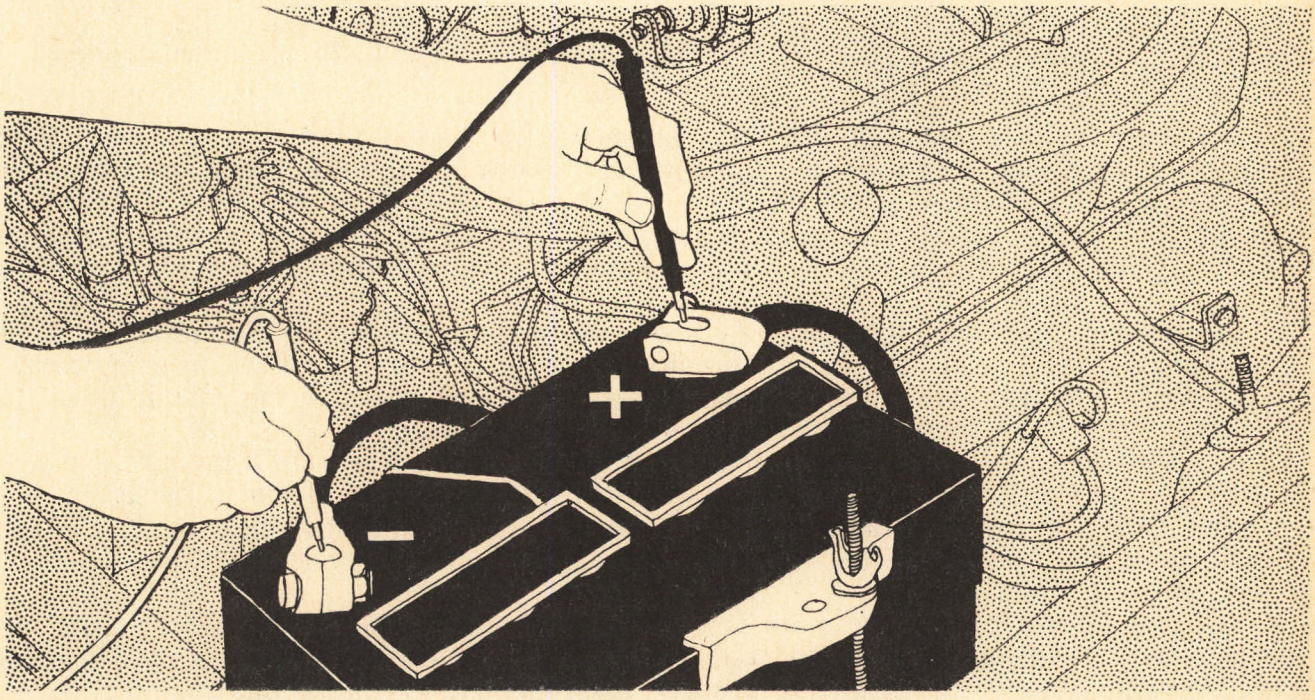
HIGH RATE DISCHARGE TEST



If after inspecting the battery and cables the battery appears good but will not crank the engine over enough for satisfactory starting, you can check it by performing a high-rate discharge test if you have access to a multimeter.

There are two types of batteries used in automobiles. One is rated at six volts capacity, the other at 12 volts capacity. Both should crank the starter for a certain length of time before their capacity drops below a certain level. First check the voltage of the battery before the starter is engaged. Connect the multimeter to the battery posts in the manner shown (multimeter plus [+] lead to battery plus lead and multimeter negative [-] lead to battery negative lead). Set the meter selector switch to read voltage. A good six-volt battery should show a reading of 5.5 volts or better. The 12-volt battery should show 11.5 volts or better.

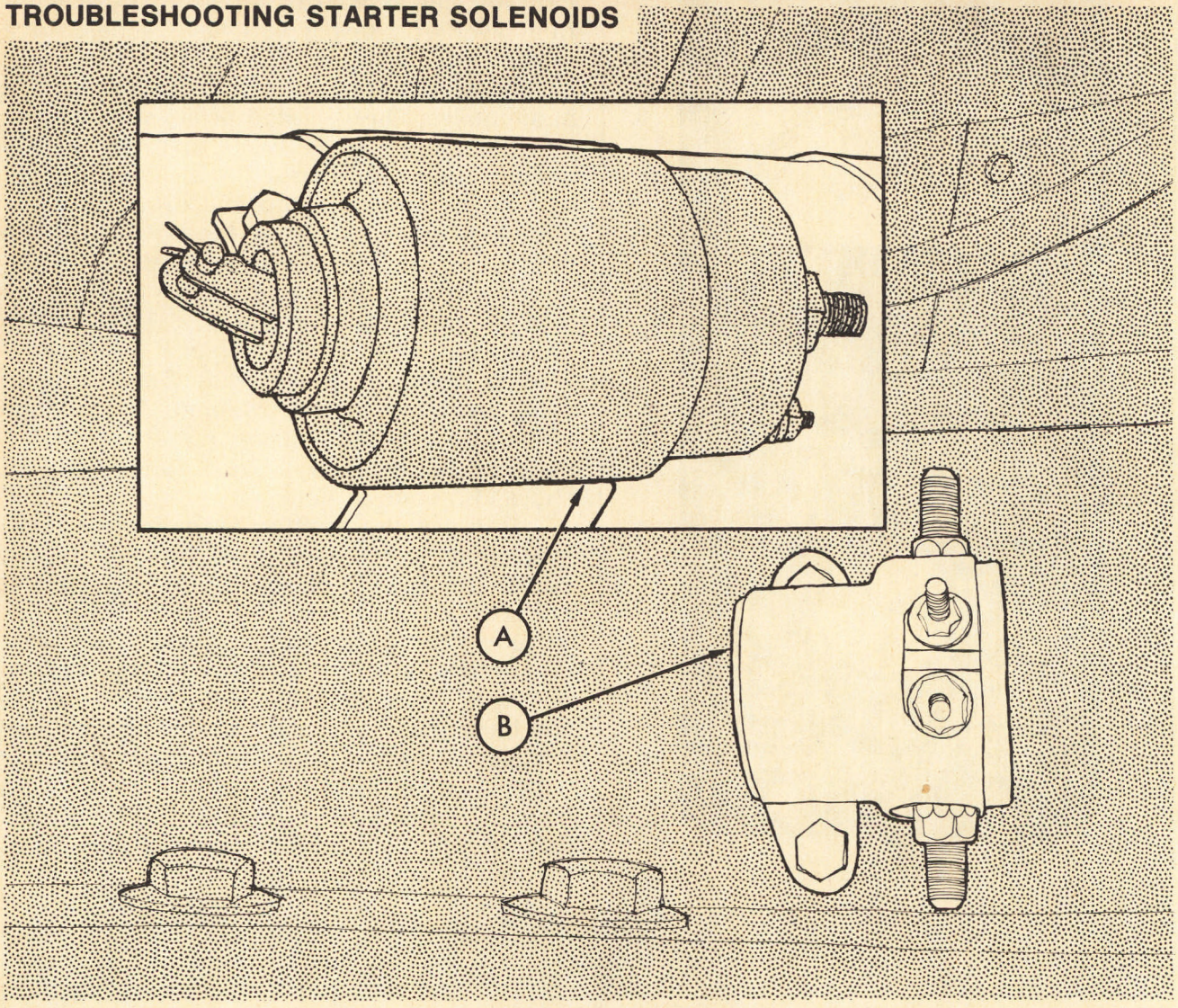
Remove the ignition lead (high-tension lead; that is, the lead from the coil to the center post of the distributor cap) to prevent the engine from firing. Then crank the starter while watching the meter. After 15 seconds of continuous cranking, the voltage should not have dropped below 4.8 volts for a six-volt battery and 9.6 volts for a 12-volt battery. If after this test or any of the other tests the battery appears to be at fault, remove it and have it recharged or replace it with a new battery. This will correct many problems, as the battery is often at fault.



NOTE: WHEN A BATTERY FAILS BEFORE IT REACHES THE END OF ITS NORMAL SERVICE LIFE, INSPECT THE REST OF THE SYSTEM TO SEE IF SOMETHING ELSE CAUSED THE PROBLEM.

TROUBLESHOOTING THE STARTING SYSTEM

TROUBLESHOOTING STARTER SOLENOIDS



The starter is an electric motor which requires a large amount of current to make it work correctly. Since it would be impractical to run the heavy wires from the battery to the starter through the ignition switch in the driver's compartment, some form of remote switching is required. This remote switch is the starter relay or solenoid. Operated by a smaller voltage from the ignition switch or starter button, it switches the heavy current on and off to operate the starter.

Some starter solenoids are separate parts of the system, located on the firewall or inner fenderwells (B), while other solenoids are actually part of the starter unit (A). In some cases, the solenoid mounted directly on the starter housing also operates the starter drive, to engage and disengage the starter motor from the flywheel.

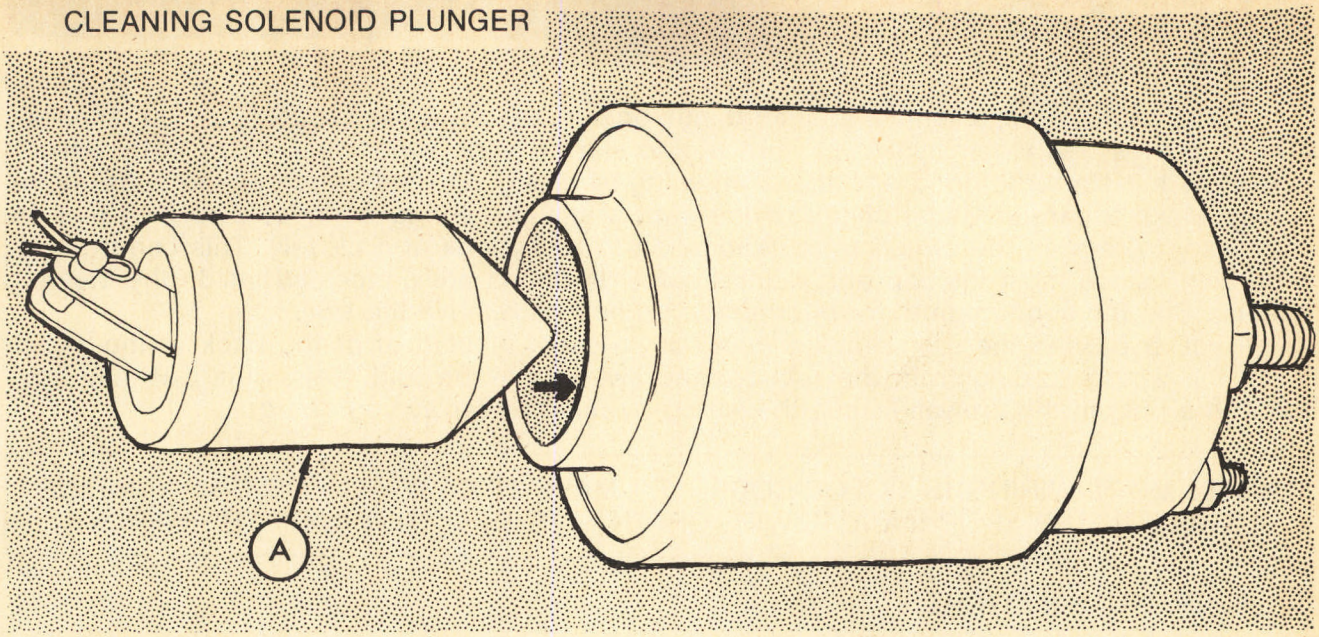
In the starter system checkout section, we showed how to determine if the solenoid was at fault by using a jumper wire to bypass it. In that section we said that if bypassing the solenoid made the starter work, the solenoid was faulty and should be replaced. This is not always necessary. Replacement will get the car fixed and back in service, but some kinds of solenoids can be repaired.

The remote solenoids are in most cases sealed relay units which must be replaced, but the solenoids which are part of the starter can sometimes be repaired. The shop manual should be consulted for information on locating and removing the starter and solenoid.

NOTE: MOST STARTERS ARE VERY DIFFICULT TO REMOVE BECAUSE OF THEIR LOCATION AND SURROUNDING EQUIPMENT.

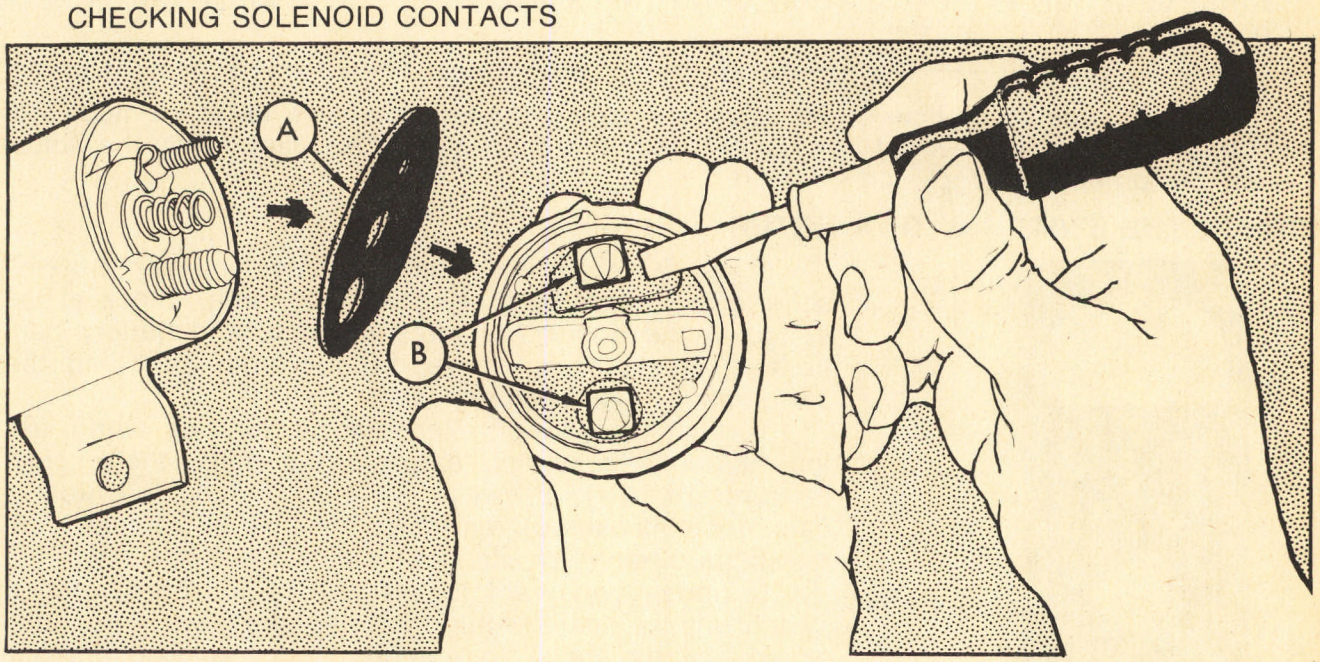
TROUBLESHOOTING STARTER SOLENOID

CLEANING SOLENOID PLUNGER



One possible problem in the solenoid is grease or dirt, which may be keeping the solenoid plunger from moving far enough to work properly. Check the shop manual for instructions on disassembling the solenoid and how to clean it. Do not grease the plunger (A) or its housing before putting it back together.

CHECKING SOLENOID CONTACTS



Whenever the solenoid operates, the contacts of the switch portion create a small electrical arc as they open and close. This will in time burn the contacts until they do not make a good connection. In most solenoids, the movable contact is a ring or plate (A), which can be turned over to utilize the unused side. The fixed contacts (B) can be cleaned and smoothed with a fine file or emery paper. On some models, the fixed contact on the hot (battery) contact can be rotated to provide a good contact surface. While the solenoid is disassembled, a careful check should be made of all wiring and electrical connections inside the dust cover on the end of the solenoid. Often troubles consist of nothing more than a broken wire or a corroded connection. Specific instructions for repairing solenoids can be found in the manufacturer's shop manual for the type of car you are working on.

TROUBLESHOOTING SWITCHES

If the starter system check showed that one of the controlling switches was suspect, they can be tested in one of several ways.

TROUBLESHOOTING THE STARTING SYSTEM

CHECK THE OBVIOUS FIRST

If the battery and solenoid are good but one of the switches (starter or neutral safety switch) proves bad when bypassed (that is, the starter works when the switch is bypassed), you know the starter is good and that something is wrong with the switch or the surrounding wiring. Make a careful visual check of the switch and the wiring connected to it. It may be necessary to remove the switch from its location to really look at it closely. This can be quite a problem, since most ignition and neutral safety switches are concealed inside the steering column. See the shop manual for information on how to remove the switch.

If you bypassed the switch at the relay or solenoid instead of at the back of the switch itself, the wiring leading from the relay to the switch may be bad. This wiring usually goes through a plug in the firewall. Trace the wiring by hand as far as you can go.

NOTE: MOST WIRING IS COLOR-CODED TO MAKE IT EASY TO FOLLOW. A WIRING DIAGRAM IN THE SHOP MANUAL WILL OFTEN GIVE THE COLORS OF THE WIRES.

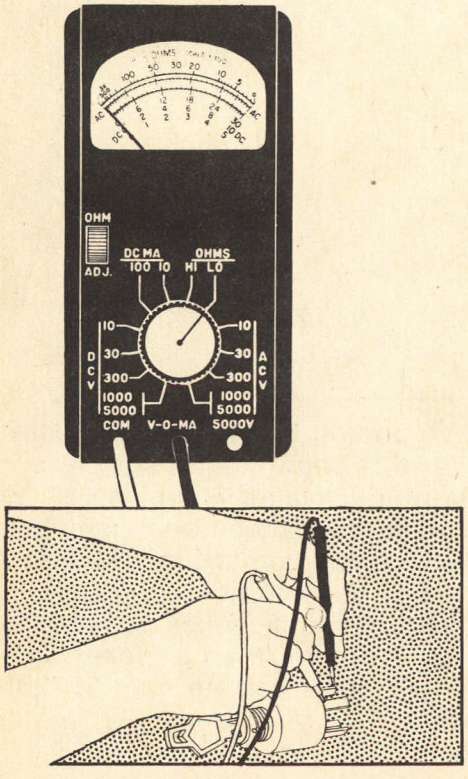
SUBSTITUTE SWITCHES

If the switch is readily available from a parts supplier, you can simply purchase a new switch and substitute it to confirm whether or not the old switch is bad.

NOTE: ELECTRICAL ITEMS PURCHASED NEW CANNOT BE RETURNED FOR REIMBURSEMENT. BE FAIRLY CERTAIN THAT THE SWITCH IS YOUR PROBLEM *BEFORE* YOU BUY.

This technique saves time on small parts which are not expensive. With some models of key-operated switches, it is not necessary to buy the entire switch assembly. Only the actual switch section need be replaced.

CHECK THE SWITCH WITH A METER



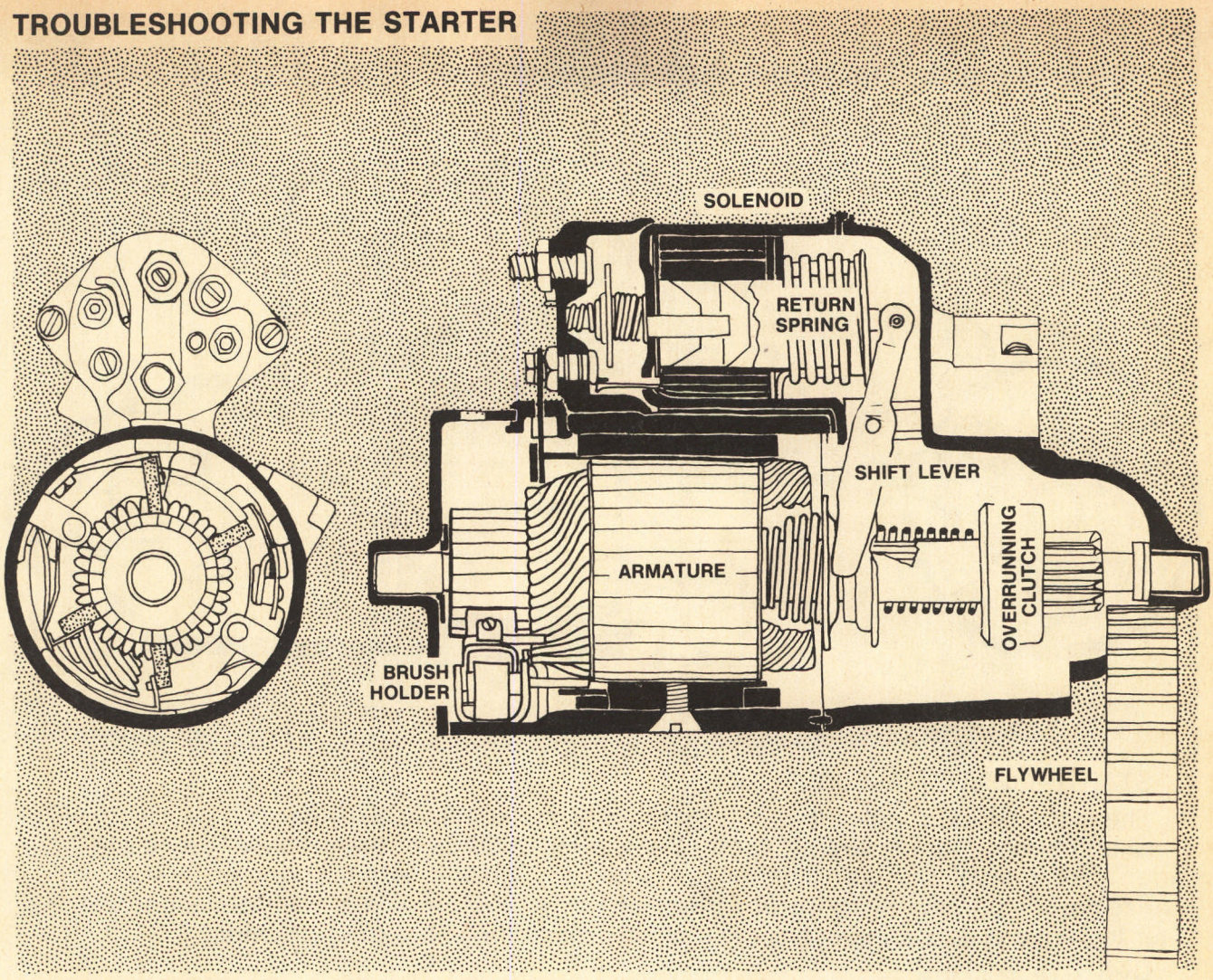
If you have a multimeter available, you can troubleshoot a switch either in or out of the circuit. Checking the switch in the circuit (all wires attached and battery connected) is somewhat more difficult than checking the switch after it has been removed.

To check the switch after removal from the wiring, use the resistance-measuring feature of the meter—the ohmmeter function. A good switch will have infinite (so great it cannot be measured) resistance when it is off and zero resistance when it is switched on.

Suppose you want to test a key-operated ignition switch with a meter. After removing the switch from the wiring, set the meter to the ohm function. Connect one side of the meter to the hot (battery) contact on the switch. Connect the other side of the meter to the "start" contact on the switch. Insert the key into the switch and turn it to start. With the switch in any position other than start, there should be no meter needle movement (infinite resistance). As soon as the switch is placed in the start position, the needle should swing to the other end of the scale, indicating a complete lack of (zero) resistance between the contacts of the switch. If the reading is not close to zero or the reading is intermittent (does not repeat the same reading each time), the switch is bad and should be replaced.

NOTE: MOST SWITCHES ARE NOT DESIGNED TO BE REPAIRED.

TROUBLESHOOTING THE STARTER



If the battery, solenoid and all controlling switches check out okay, there is very little left in the starting system except the starter itself that can cause a no-start problem. If you have not removed the starter to check the solenoid, begin testing the starter by first carefully examining the wiring and connections around it.

NOTE: THE STARTER IS SUBJECT TO MUCH EXPOSURE TO DIRT AND OTHER DEBRIS BECAUSE OF ITS LOCATION NEAR THE BOTTOM OF THE ENGINE. IT MAY BE NECESSARY TO CLEAN THE STARTER BEFORE EXAMINING IT. CLEANING MAY TEMPORARILY CURE A FAULTY CONNECTION PROBLEM, BUT IT WILL SOON RETURN UNLESS A COMPLETE CHECK AND REPAIRS ARE MADE.

The following is a list of the things that could be wrong with the starter:

BAD CONNECTIONS

This means dirty or broken connections or wiring. Replace or repair wiring. Corrosion or oil buildup on the outside of the starter case can cause the starter to malfunction.

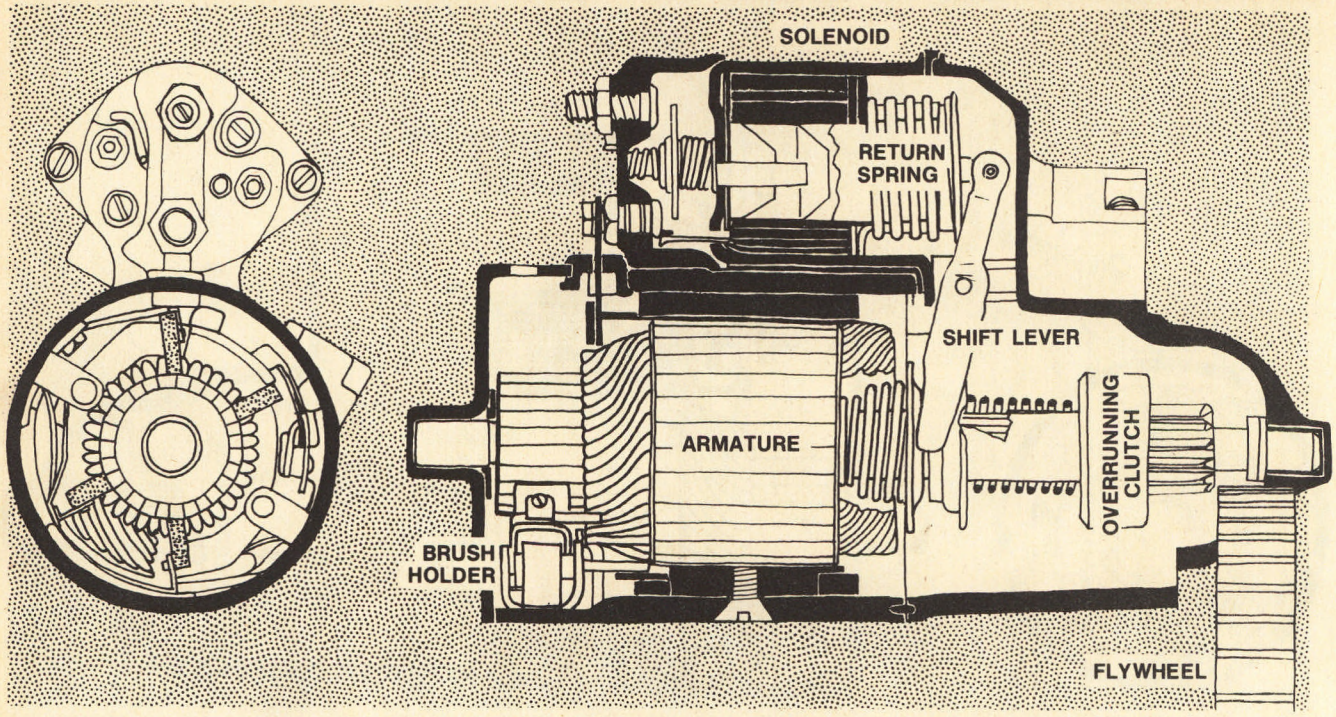
BAD GROUND CONNECTIONS

The electrical system of the starter is "grounded" to the engine. Check to make sure that all bolts holding the starter to the engine are tight. Loose bolts can also cause binding of the starter drive.

INTERNAL WIRING PROBLEMS

The internal wiring of the starter is quite complicated and should be left to a professional mechanic to check, as it requires several types of special tools. You can disassemble the starter using the shop manual and inspect it for obvious signs of damage, but it usually requires a trip to the shop for repair.

TROUBLESHOOTING THE STARTING SYSTEM



STARTER DRIVE MALFUNCTION

The starter drive couples the motor portion of the starter to the ring gear on the flywheel to make the engine crank over. This drive can be the source of the problem, especially if the starter spins but will not crank the engine when the ignition switch is turned to start. If you have removed the starter, try to turn the starter by hand. If it is binding, chances are that either the drive or a bearing is bad. You must replace the entire drive assembly.

HYDRAULIC LOCK

Not really a starter malfunction, this occurs when large amounts of some fluid (gasoline, oil or water) get into the cylinders of the engine and prevent movement of the engine. These liquids are not compressible, so if they get into the cylinders, the engine becomes "locked." If you suspect this, remove all the spark plugs and try to crank the engine over. If it now cranks easily and you can see any fluid coming from the spark plug holes, the problem is a hydraulic lock.

If the fluid is gasoline, it indicates a stuck float in the carburetor. If it is water, there could be a blown head gasket or cracked block or head. If it is oil, the oil could be too thin.

NOTE: THIS PROBLEM USUALLY OCCURS AFTER THE CAR HAS BEEN RUNNING HARD ON A WARM DAY.

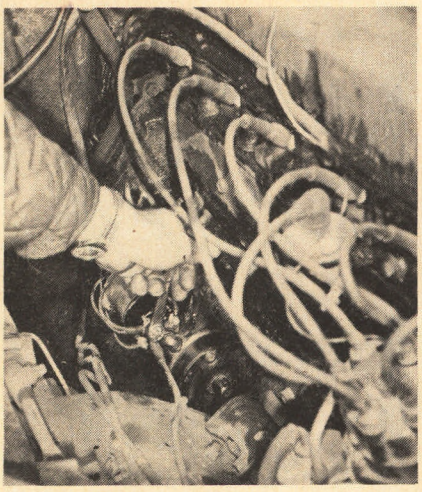
COLD WEATHER INFORMATION

Starting system performance is greatly reduced in cold weather. To prevent problems, the battery should be kept fully charged. Because of the location of most starters, snow, ice and slush can become packed around the starter, and it may freeze. The salt used on roadways during bad weather can cause considerable corrosion if left on the underside of the car, and this can affect the starter. Keep the underside of the car as clean as possible.

HOT WEATHER INFORMATION

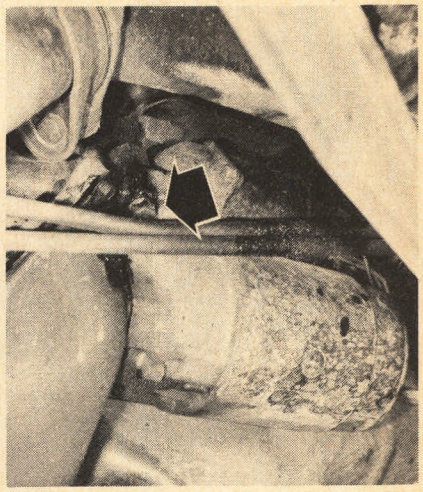
Some starting problems, such as slow starting, can be the result of a cooling system malfunction rather than a starter problem. High engine temperatures can increase internal friction in the engine, putting an extra load on the starter. If you experience continued hard starting problems (slow starting) during hot weather, check out the cooling system to make sure that it is functioning properly.

HOW-TO: Starter Removal

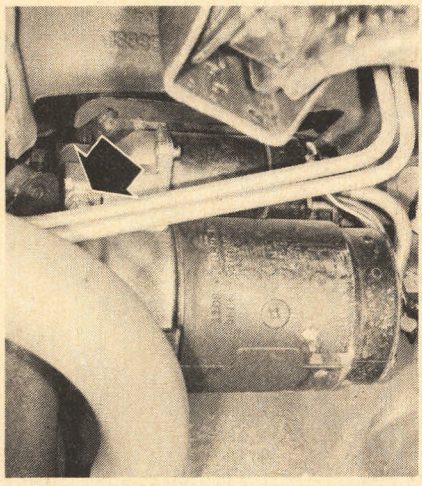


1. Solenoid disconnect is done from under hood. On some late-model cars, plumbing is heavy, so you'd do better to work from underneath.

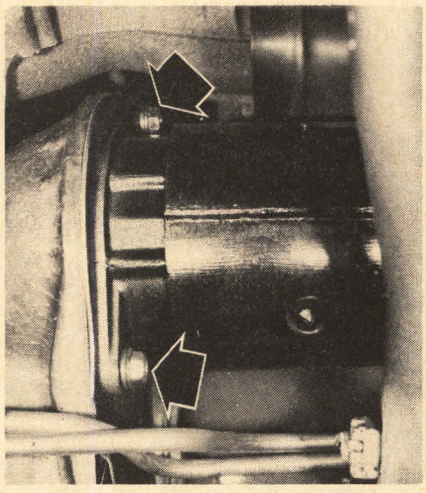
2. Once solenoid is disconnected, removal of two bolts will allow starter to be pulled. Bolt location differs from year to year and car to car.



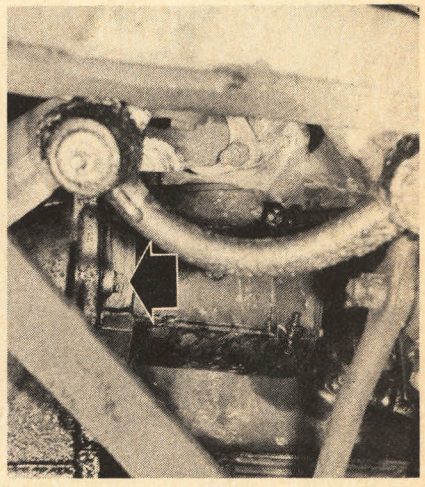
3. Starting motor removal from majority of GM cars is best accomplished from underneath. There's another bolt on the side opposite from the one marked.



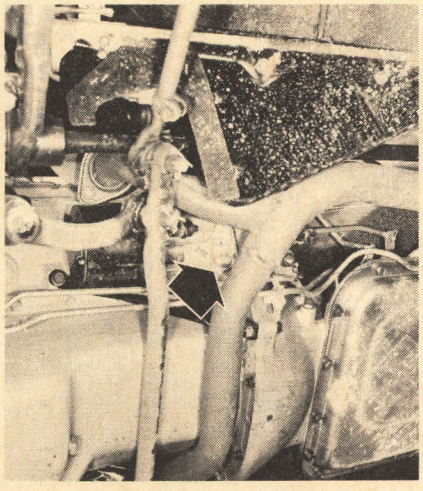
4. Dual exhaust on same GM car as in photo #3 shows how access to starting motor can vary, depending upon the particular car and how it's equipped.



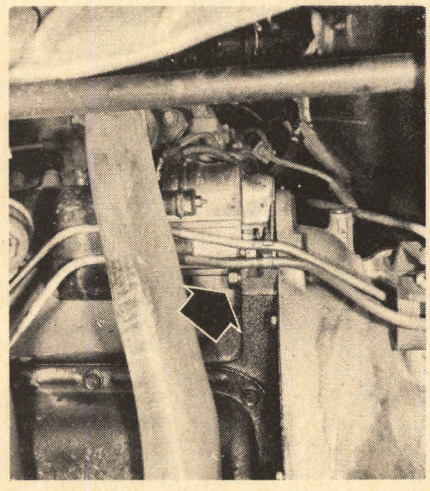
5. FoMoCo starting motor is mounted to flywheel housing with two horizontal bolts. Access on '73 Ford LTD is exceptionally easy compared to many cars.



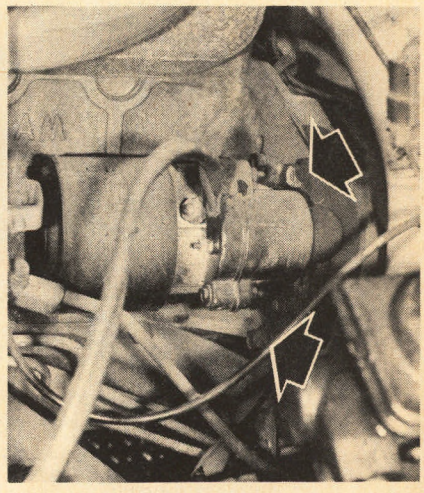
6. Here's a late-model T-Bird starter mounted exactly as in LTD, but note how access is obscured by crossarms and suspension linkage.



7. Getting at this '73 Valiant starter is no picnic. Steering linkage and dual exhaust pipes hamper removal of the lower bolt, making removal tedious.

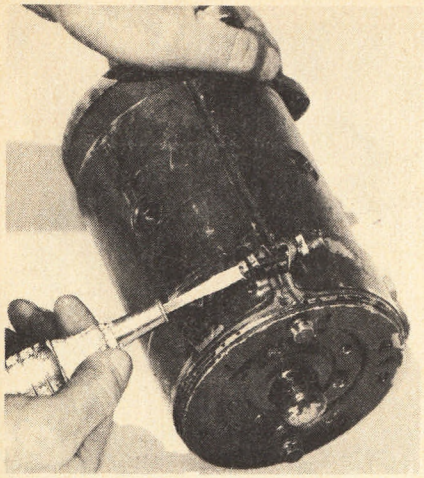


8. Lower bolt on this '72 Le Baron is difficult to get to. Upper bolt on Chrysler Corp. V-8's is reached from under hood, with equal difficulty.

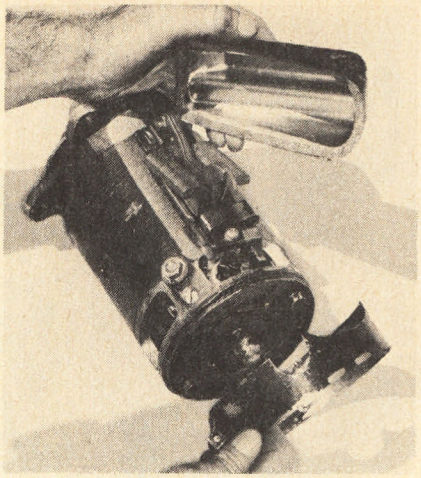


9. Easiest starter to remove is that on a Chrysler Corp. Slant-6. As on this '72 Duster, the starter comes out easily from under the hood.

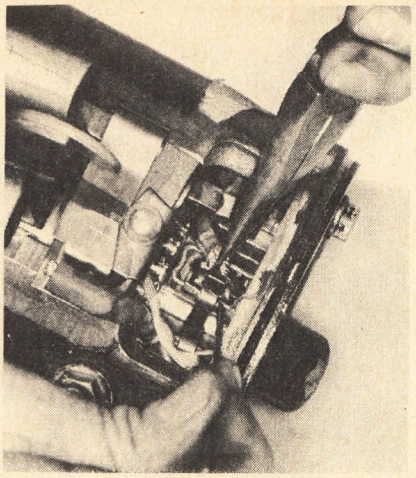
HOW-TO: Ford Starter Teardown



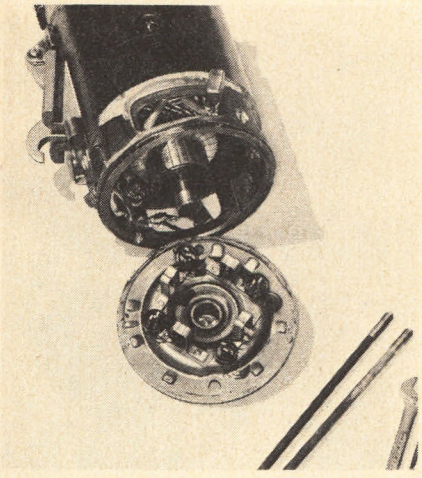
1. Ford starters can best be removed by disconnecting starter cable at relay (drop steering idler arm on Montego), take off mounting bolts.



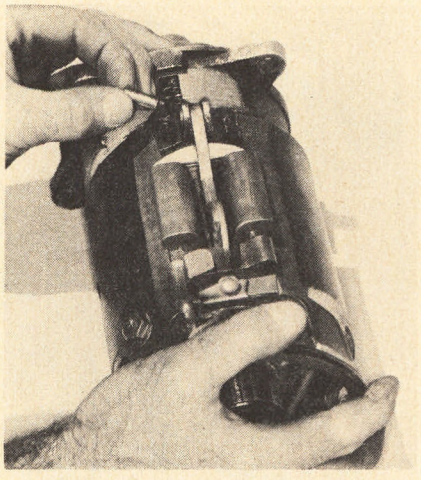
2. To disassemble this Ford starter, loosen and remove the brush cover band, starter drive plunger lever cover and the cork gasket under it.



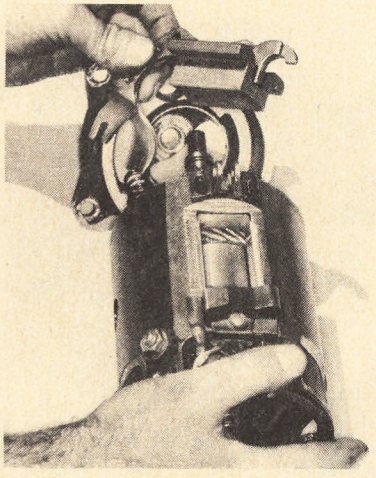
3. Next insert needle nose pliers and a hook made from a large cotter key, and lift out the brushes so the end plate can be taken off.



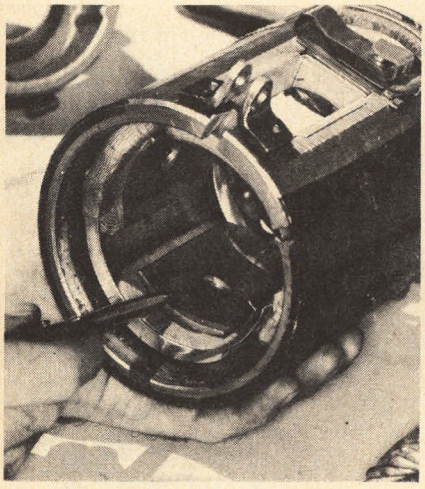
4. With the brushes now out of the way, you can fully remove through-bolts and pull off the starter end plate with the brush springs on it.



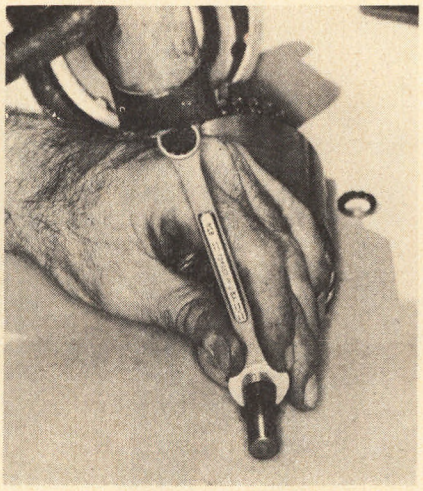
5. Extract pivot pin which retains lever. Now is a good time to look at the contacts at the other end of the lever to be sure they are OK.



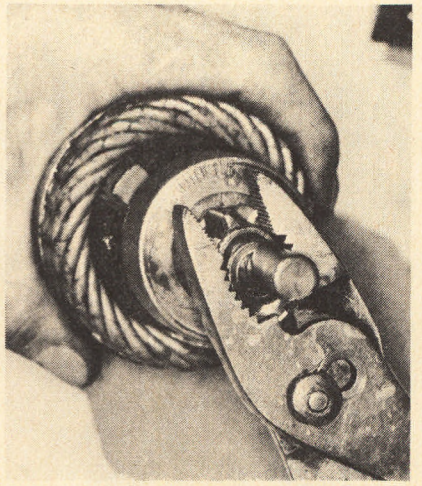
6. Starter gear plunger lever can now be lifted out. Remove armature. Use brush or air to clean field, coils, armature shaft, brush end plate, etc.



7. Inspect pole shoes to see if the armature has been rubbing them. If it has, the armature bearings have gone away, and shaft has sagged out.

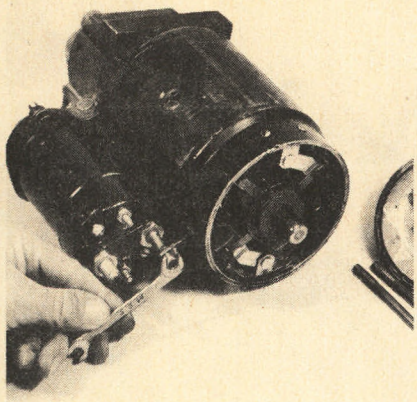


8. If starter drive gear assembly is to be reused, remove stop ring retainer and the stop ring from the end of armature shaft; remove drive.



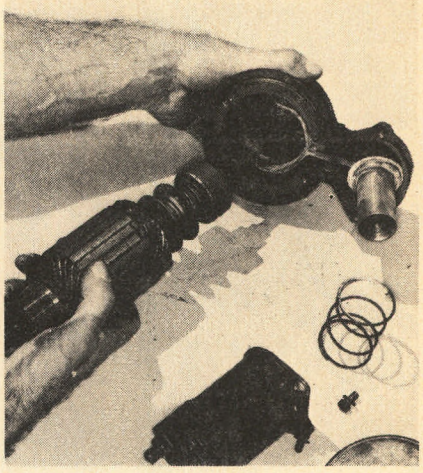
9. Place the drive gear assembly on the new armature with new stop ring. Install the fiber thrust washer on commutator end of armature shaft.

HOW-TO: Delco-Remy Starter Teardown

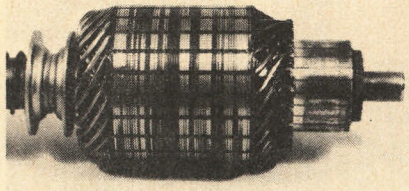


1. To disassemble, check Delco-Remy starter, remove through-bolts off commutator end frame, then pull motor connector strap terminal screw.

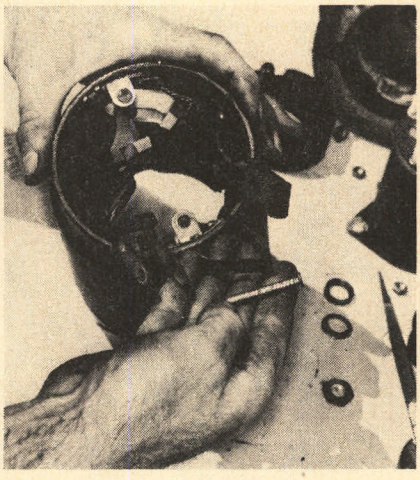
2. Slide field housing away from lever and nose housing. If solenoid is OK, and you're just checking armature, leave solenoid alone.



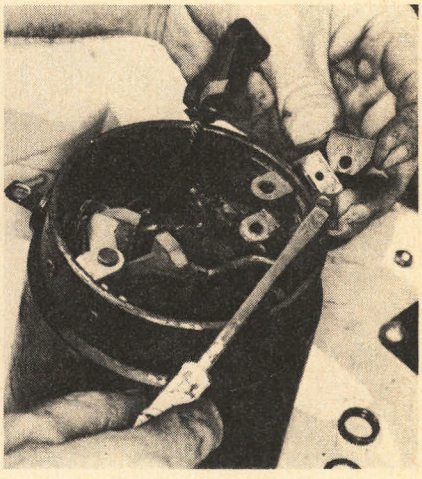
3. Once armature is out of field housing, check commutator. If it's grooved, rough, or out-of-round, it must be turned down smooth.



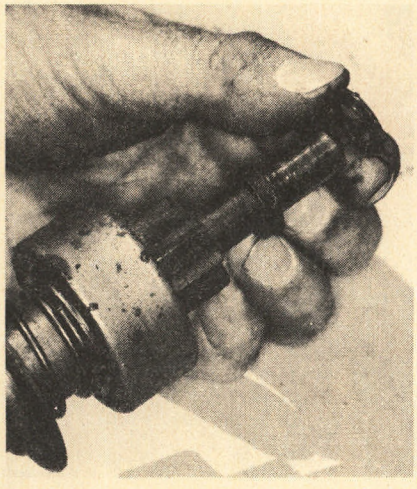
4. If armature touched or rubbed against field coils, chances are bushings in commutator end frame are gone and should be changed.



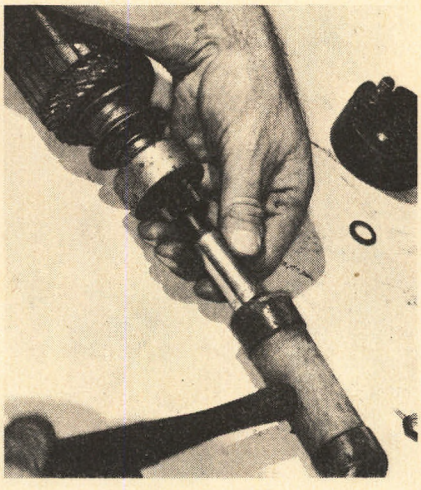
5. Worn brushes can cause a no-start problem. A pin retains entire assembly, which, when removed, allows brushes to be replaced.



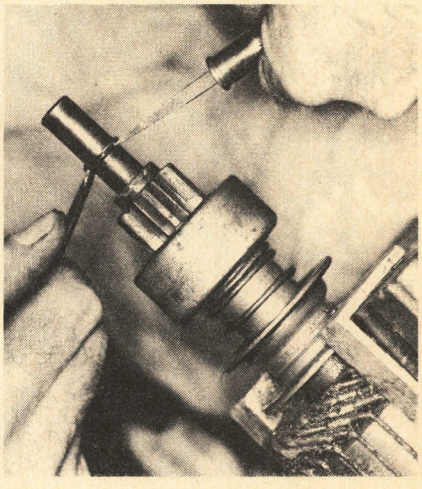
6. Brushes are attached to holders with small screws. No solder needed. Disassemble one pair of brushes at a time, use other pair as example.



7. Drive is kept on armature shaft by three pieces. First take thrust collar off end of shaft. Note flange goes toward body of armature.



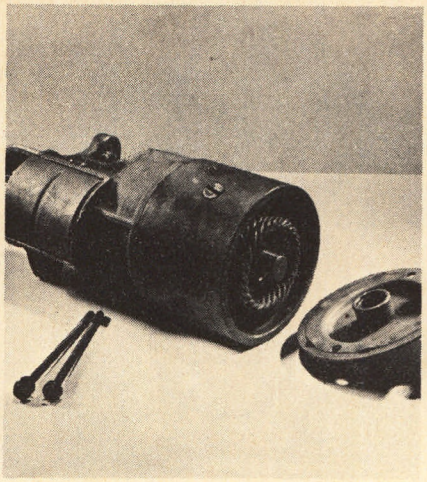
8. Next, retainer must be driven back along armature shaft. Use a deep socket and plastic-head hammer; don't punch it off with a ball peen.



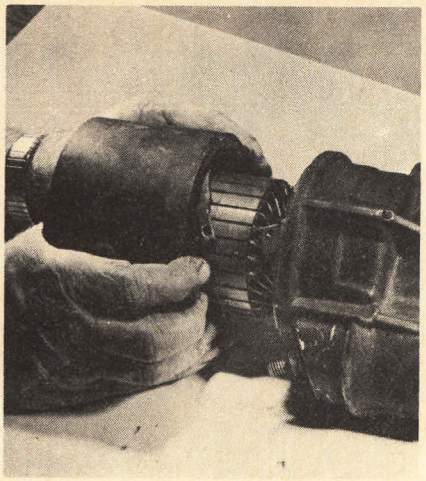
9. Once snap ring is exposed, remove it with two screwdrivers. Drive assembly can be slid off armature shaft and replaced, if necessary.

HOW-TO: Chrysler Starter Teardown

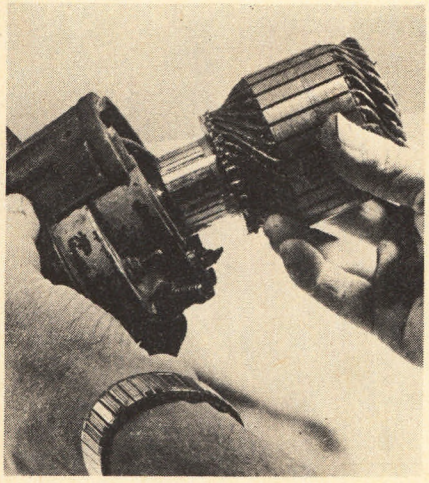
1. Begin removing MoPar starter by disconnecting battery ground strap, hot cable from starter, and solenoid lead wires at solenoid terminals.



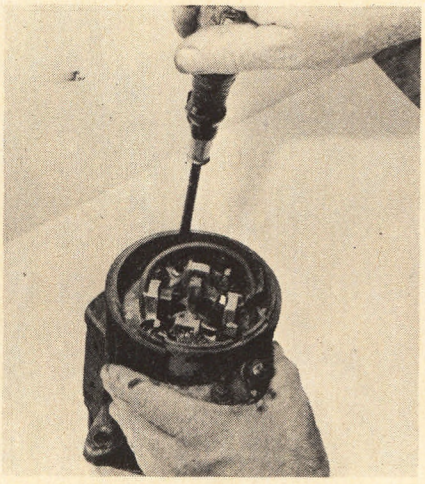
2. Remove stud nut (bolt holding starter to bellhousing); slide trans oil cooler tube bracket off stud prior to removing starter, end head.



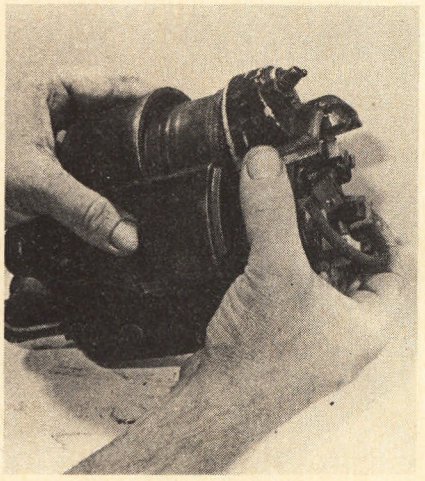
3. With long bolts removed, you can pull frame off to expose terminal screw, wrapped wire connection of shunt field at brush terminal.



4. Armature can now be pulled up and out of gear housing, starter frame and field assembly. Then remove the steel and fiber thrust washers.



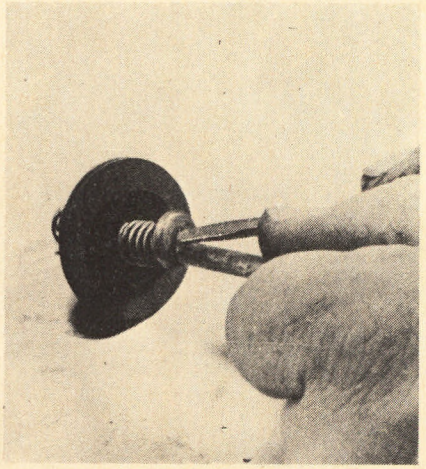
5. Extract brush holder plate screw before taking off steel insulation washers from solenoid. Remove brush hold plate (with brushes) as unit.



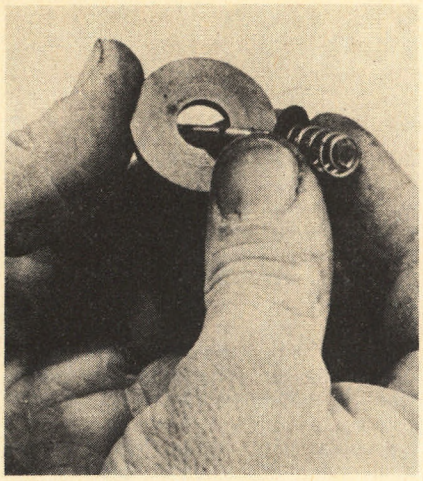
6. Now, solenoid/brush assembly can be pulled from gear housing well, the nut, steel washer and sealing washer from battery terminal.

7. After nut on solenoid terminal is off, solenoid lead wire to brush terminal post must be unsoldered so solenoid assembly can be removed.

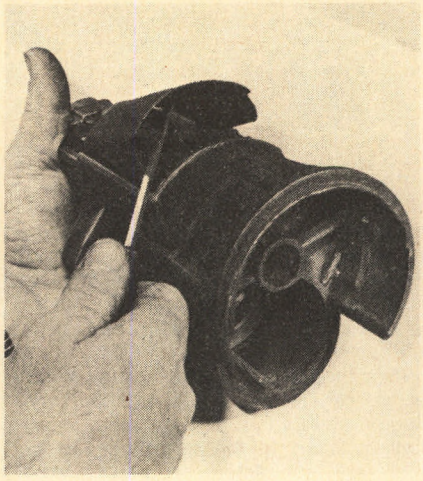
8. Brass washer contact disc that makes the electrical connection between the battery and starter, is subjected to pitting and/or burning.



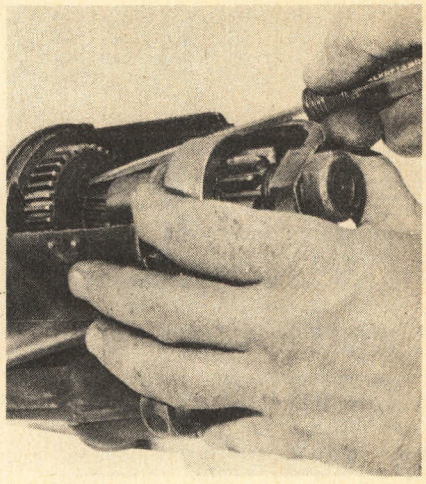
9. The contact disc can be removed, replaced or reversed by releasing it from contact stud, plunger. Pop off snap retainer holding it on plunger.



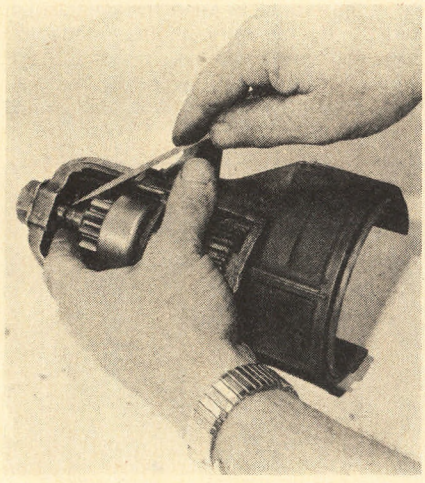
10. After removing the contact disc, turn it over and return it to the plunger. This new, fresh side saves you from buying a new contact disc.



11. In order to get at the starter drive, all you have to do is grab one of your trusty screwdrivers and pry off the dust cover.

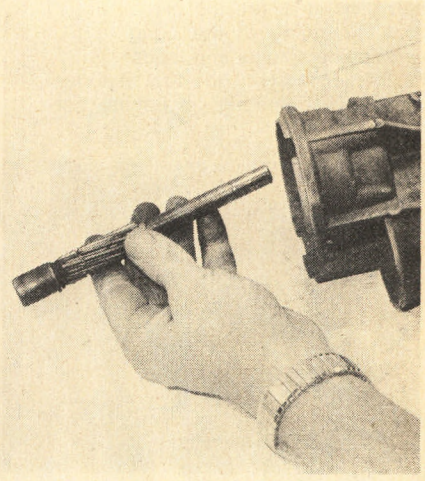


12. Release U-shaped retainer that positions driven gear on pinion shaft. Be careful; retainer is under pressure and can spring away.

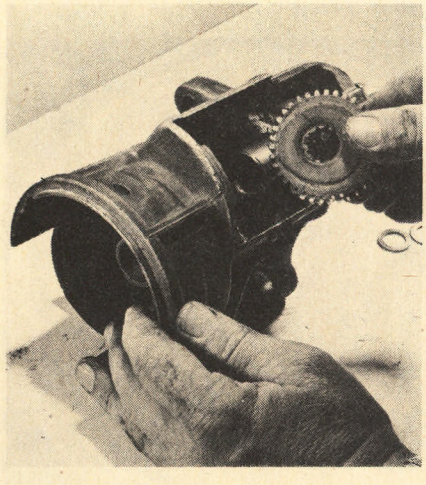


13. Retainer ring on front of pinion shaft can now be released. Don't use a spreader any larger than shaft's O.D. or ring can be damaged.

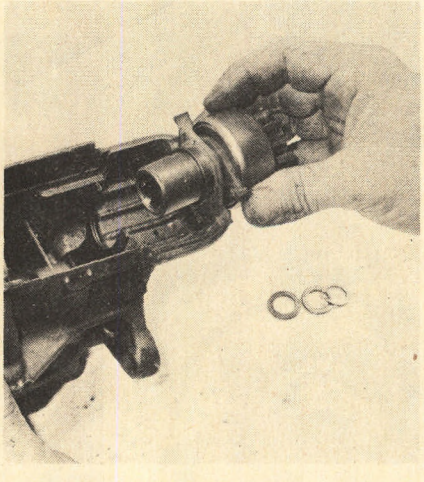
14. Tap pinion shaft toward rear of housing. Extract retaining ring, thrust washer, clutch, pinion (shifter forks, nylon actuators) as unit.



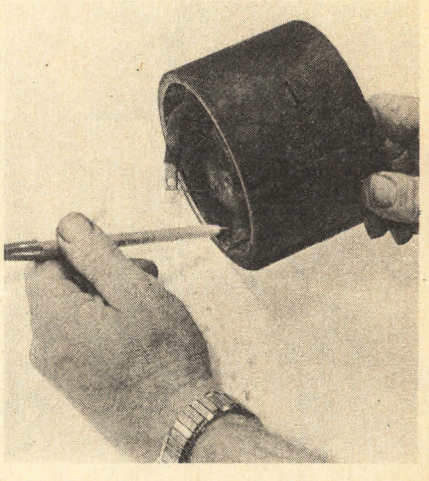
15. With pinion shaft removed from rear of the starter housing, check it carefully for any burrs, cracks or other signs of wear or damage.



16. Large friction washer on driven gear is subjected to wear because it absorbs shock of large gear being driven to rear of the housing.



17. Clutch assembly can be removed as well as the clutch shifting fork assembly. Do not soak in solvent; wipe all pieces with a clean cloth.



18. Check the wiring on inside of field for breaks or signs of burning. Make sure screws that hold pole shoes in are good and snug.

Ignition System

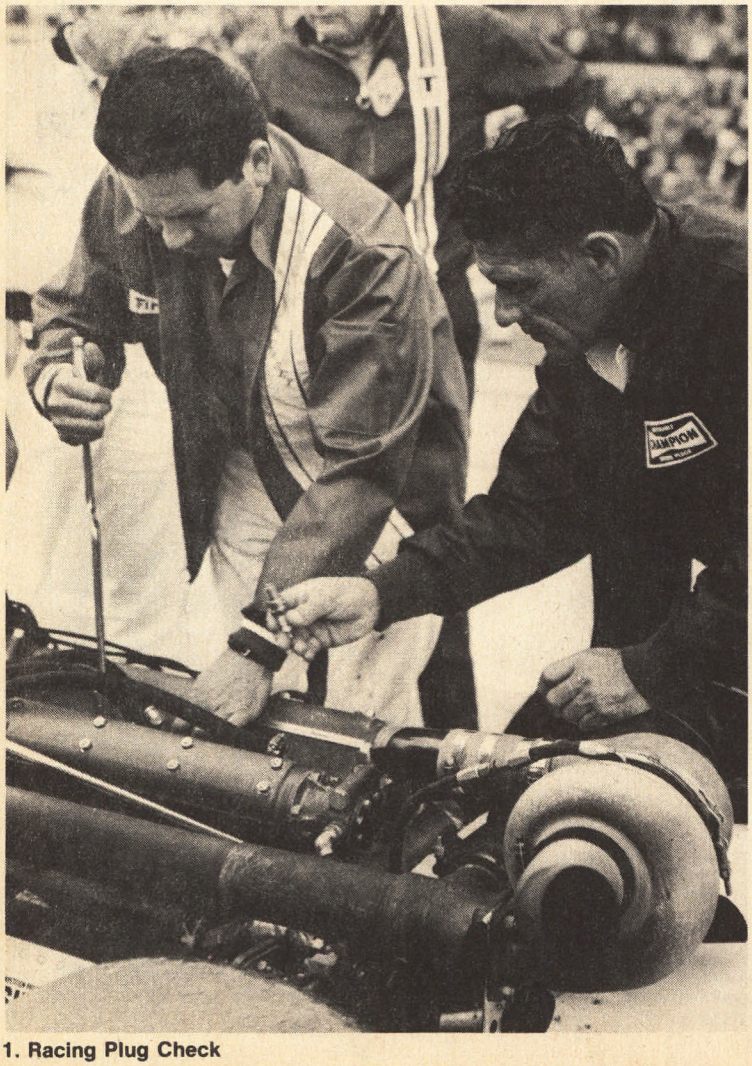
The ignition of an internal combustion engine has very probably had more development work done on it than any other part of an automobile. Even so, it is still a long way from being perfect. Just in the past few years we have seen transistor ignitions appear that weren't much good and capacitor discharge ignitions come on the scene that were a lot better. The ignition has a very difficult job to do.

As the entire purpose of the ignition is to fire the fuel/air mixture compressed in the engine combustion chamber, with only a storage battery as power source, the system's basic functions are quite clear: 1) Convert the relatively low voltage of the storage battery to the high voltage needed to fire the plugs, and 2) Control the timing of the firing to suit varying engine speeds and loads.

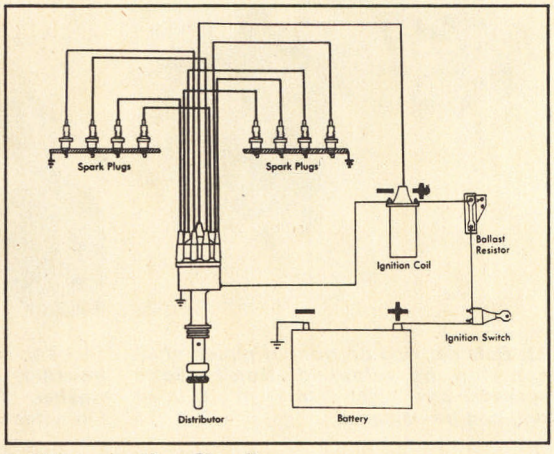
The ignition system has two electrical circuits. One, operating on battery current and controlled by the ignition switch and distributor points, is called the *primary* circuit. The *secondary* circuit carries high voltage current induced in the coil and consists of a high tension cable between the coil and distributor, the distributor rotor and cap, the spark plug cables and the spark plugs.

When the ignition switch is turned on, the current flows from the battery through the switch to the coil primary windings, then to the distributor points which are connected to ground. Any time that the distributor points are closed there is a continuous flow of current from the battery through the ignition switch through the coil primary and through the points. This flow of current through the coil primary creates a magnetic field which stays there as long as current is flowing. As the engine rotates, the distributor cam pushes the points apart, which breaks the primary circuit and stops the flow of current. When the current flow ceases, the magnetic field in the coil collapses—which creates a high voltage in the secondary windings in the coil. The secondary windings are connected to the spark plugs so that the high voltage can jump the spark plug gap, thus firing the mixture and making the engine run. The distributor cam is timed to the engine so that it opens the points at exactly the right moment, when the combustion chamber is full with the fresh charge of fuel/air mixture.

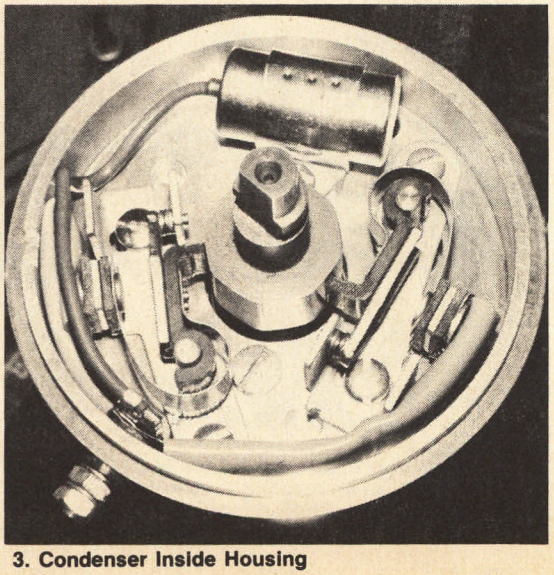
A condenser is connected between the coil primary and the points. The condenser's purpose is to assist in the quick collapse of the magnetic field in the coil. Many textbooks state that the condenser is in the circuit to keep the points from pitting. If that were all the condenser did, you could remove it and the car would still run. We have never found an engine with battery ignition that would



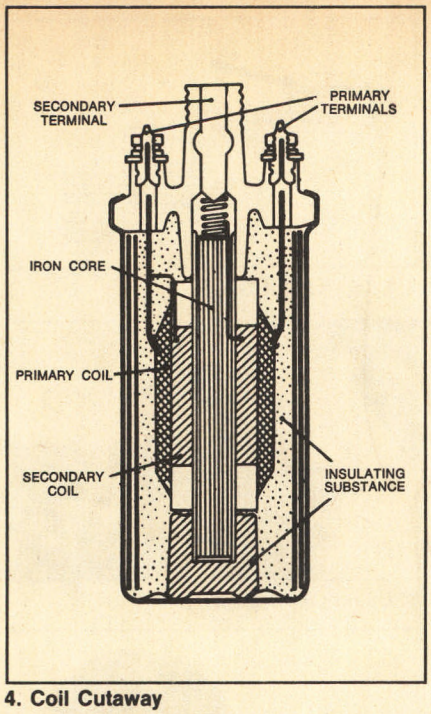
1. Racing Plug Check



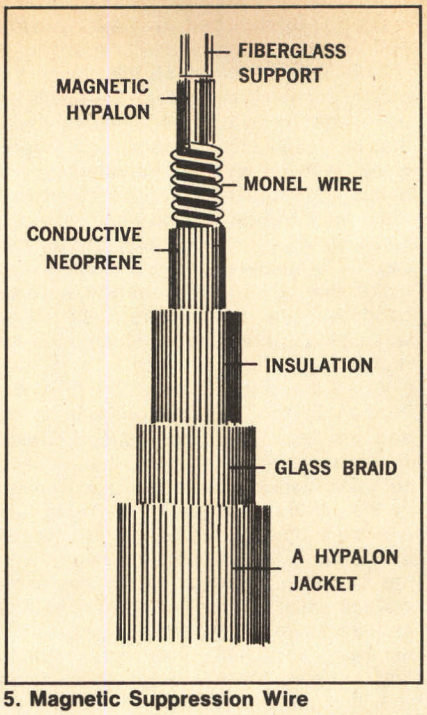
2. Battery Ignition Circuit



3. Condenser Inside Housing



4. Coil Cutaway



5. Magnetic Suppression Wire

run without a condenser. So this proves, at least to us, that the condenser does much more than just keep the points from pitting. Now that we have a general idea of how the ignition system works, let's look at the various components.

THE COIL

An automotive coil is an induction transformer not much different from the little transformers that are used to run toy trains. A train transformer takes 110 volts out of the wall outlet and converts it to a safe low voltage so that your hair doesn't stand on end every time you touch the tracks. The ignition coil works the other way around. It takes the 12 volts that is available at the battery and changes it to 10,000 or 20,000 or even 30,000 volts, whatever is needed to jump the particular gap at the spark plug.

Every modern coil has three terminals—two small threaded posts for the primary and a large center tower which is the connection for the secondary. Inside the coil is an iron core with the primary and secondary windings wound around it. The ratio of turns between the primary and secondary windings determines how big the step-up in voltage is between the battery voltage and secondary voltage. Because the step-up is from comparatively low battery voltage to very high spark plug voltage, the primary has relatively few turns and the secondary has many.

Current flow in the secondary is created in the coil and flows out along the secondary lead to the distributor and then to the spark plugs. If you study electrical circuitry, you will be told that all current must return to its source in order to make a complete circuit. If the circuit is broken anywhere the current will not flow. The theory works fine with low voltage but it is a source of embarrassment to many automotive instructors when they attempt to explain the path of ignition system secondary voltage. One end of the secondary winding goes out to the spark plug. The other end may be grounded to the coil can, or in most cases is grounded to the primary windings. The standard explanation of the secondary current flow is that it goes out through the spark plug wire, jumps the gap at the plug and then returns through a ground path into the battery and back through the primary windings. It may be very convenient to explain secondary current flow in this manner but the theory just doesn't hold water when you analyze it.

The next time somebody tells you the secondary current has to have a return path through the coil winding, ask him to reach over and touch a bare spark plug wire tip while the engine is running. He probably will refuse because he knows that the secondary current will go into his body, which can in no way be a return path to the coil windings. If you want to experiment even further, get a long spark plug wire and plug it into one distributor tower with the engine running. Walk around with the wire in your hand and touch it to various objects. You will find that the spark will jump to just about anything. In fact it will jump to any mass of electrons big enough to attract it.

When removing or installing primary wiring connections to the coil, be sure to observe proper polarity. These connections are marked either positive (+) and negative (-), or "batt." (battery) and "dist." (distributor). Most cars are currently using 12-volt ignition systems with negative ground, but earlier Fords to 1956 with 6-volt systems used positive ground. When replacing coils it is important to use only those that match the rating and polarity of the system. Reversing polarity or using the improper voltage-rated coil will result in poor voltage output and insufficient power to fire the plugs.

CONDENSER

The condenser is attached across the breaker points of the distributor. Some

1. Many advances in ignition design have come from racing applications. Reading plug condition after a run helps engineers determine sources of power loss and what adjustments are needed to improve engine efficiency.

2. Simplified ignition circuit shows basic components in primary and secondary circuits.

3. The condenser (also called the "capacitor") can be either inside or outside the distributor housing. It stores primary circuit energy when the points are open and hastens the collapse of the magnetic field in the coil.

4. Cutaway of typical coil shows primary and secondary windings with insulation. Iron core is necessary to create magnetic field.

5. Magnetic suppression wire has a complicated construction.

6. Here's the wire that practically every mechanic is familiar with—good ol' metallic core with rubber insulation, neoprene outer covering.

7. This "whisk broom" is really the inner core of one brand of resistance spark plug wire. The filaments are impregnated with carbon and encased in a nylon sheath.

8. Belden IRS has a 1-piece tubular conductor with a strengthening nylon cord through its center and rubber insulation with a neoprene sheath.

9. This is really old stuff—metallic wire, with rubber for insulation, is further coated with a mixture of cotton and lacquer.

distributors have the condenser installed inside the housing, others are externally mounted. In either case it has only one lead wire, the other connection being the outer case or mounting bracket which is grounded. The wire lead is connected to the coil primary usually at the same place as the wire from the coil to the distributor points. The condenser is a very important part of the point switching system and is in the circuit to speed up collapse of the magnetic field in the coil. It is, in effect, a small storage tank with capacity that is balanced to the circuit.

Condensers develop internal leaks that disturb this balance, the effects of which show up in the form of metal transfer on the points themselves. Even a new condenser in perfect condition will cause this metal transfer if it is not of the proper capacity. Condensers are rated in microfarads (mfds.), which can be measured with a condenser tester.

Condenser capacity usually runs from .21 to .25 mfds. If you have a problem of rapid point pitting on a particular car, it is possible to reduce the pitting by selecting the proper capacity condenser. Condenser selection according to capacity is rarely done nowadays because of the amount of time it takes.

Examination of the points will indicate over- or under-capacity of the condenser by applying the "minus-minus-minus" rule: *If the minus (negative) point is minus metal (pitted), then the condenser is minus capacity.* Increasing condenser capacity would correct the condition. Conversely, if the pit were on the positive point, then the condenser would have too much capacity, and another condenser with less capacity would be the solution. This applies to both 6- and 12-volt systems, with either negative or positive ground.

Few mechanics bother to test condensers—it's easier to put in a new one. However, many apparent cases of low-capacity condenser damage result from poor ground contact between the condenser case and the distributor. A new condenser won't help unless the mounting area is kept clean and bright.

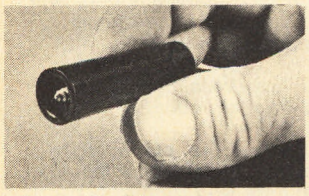
Delco introduced a new unitary points/condenser unit for use on some '72 GM cars. Mounted on the points, the condenser is connected to the insulated point arm by two thin ribbons of metal that flex each time the points open and close. With no wire lead connecting the points and condenser, there's much less radio interference and no need to use a metal shield over the points. But as this design is somewhat more complex to make than the older separate points/condenser, the manufacturer believed he was justified in asking a higher price for replacement units.

When the price commission took exception to the replacement unit price and insisted that it be reduced, Delco simply removed it from the market, and so what started out as an improvement in the ignition system turned into just one more small example of governmental interference in automotive design, with the customer coming out on the short end, as usual. To replace the points and condenser in this distributor now, it's necessary to install a new breaker plate first, because the one originally supplied with the unit has no hole for condenser installation. A conversion kit is available through GM dealers complete with new breaker plate, but its installation adds $15-$20 to the customer's bill for the initial tune-up.

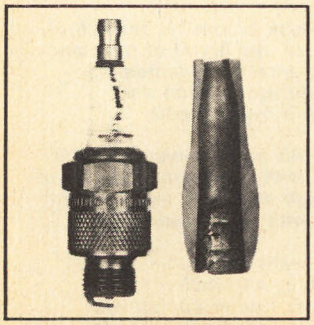
SECONDARY WIRING

The secondary or high-voltage wiring—those connections from coil tower to center of distributor and the individual ones from distributor to spark plugs—differ a great deal in construction and capacity from those used to carry the current from battery to coil (primary wiring).

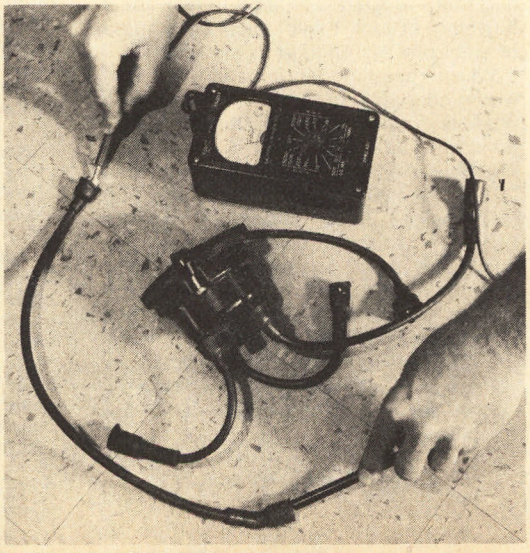
Unlike the primary wire, cable used in the secondary circuit must be heavily insulated to contain the high voltage current it carries. Most cars have cables sheathed with Hypalon insulation. This has good resistance to oil damage but withstands the higher underhood temperatures of today's cars better than the neoprene insulation which was used in the past. If you replace the spark cables, stay away from glossy plastic-insulated



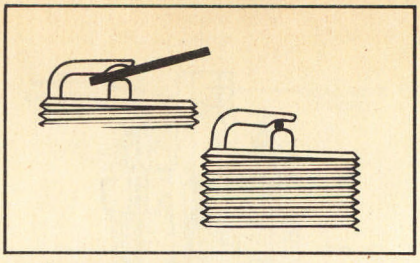
1. Lump Resistor



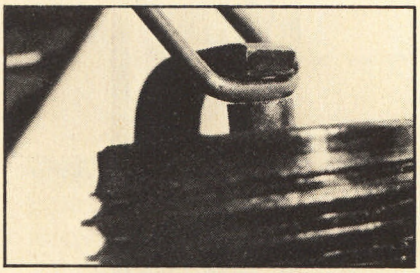
2. Defective Plug Boot



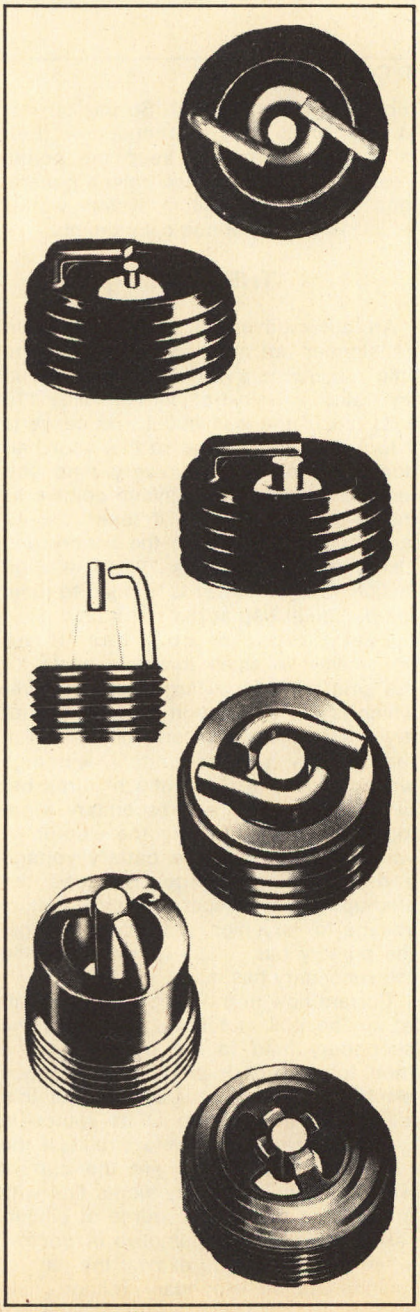
3. Checking Wiring Resistance



4. Effect of Flat Gauge



5. Using Gap Gauge



6. Electrode Types

1. If you don't have resistor wires but want to cut down on radio interference, insert this lump-type resistor between the coil and distributor. Resistance is about 10,000 ohms.

2. Plug boots that cover the plug can sometimes be the catalyst producing flashover. Plug insulator is ruined by carbon track. Both plug and boot must be replaced.

3. All ignition wiring, resistance type or otherwise, can be checked with an ohmmeter. Extremely high reading reveals defective wires.

4. No matter how careful you are, you just can't gap plugs with a flat feeler gauge. You must use a round wire gauge.

5. If the spark plug gauge will pass through the gap with a slight amount of friction, then you can be sure that the gap is correct.

6. Spark plug ground electrodes come in many different shapes and sizes. The multiple-electrode designs are good only on industrial and aircraft engines that operate at constant rpm. They have a tendency to foul if used in a car where the engine is idled in heavy traffic.

7. Champion gap tool is handy, since individual gap gauges are retractable. Gapper is less likely to make a mistake with this setup.

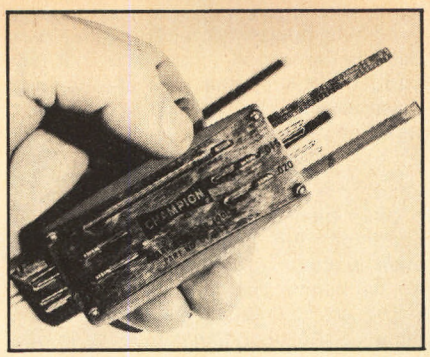
8. Core bridging—buildup of combustion chamber deposits between insulator and shell—is caused by poor oil or bad oil control.

9. Combustion chamber deposits can also lodge between the electrodes, thus shorting out the plug. Cleaning and regapping are the answer.

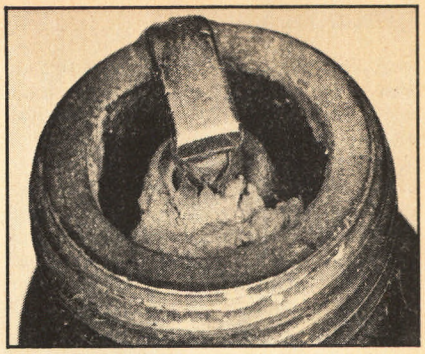
10. This is what can happen when dirt, dust, and sand enter with the fuel/air mixture. Ineffective air cleaner and bad intake gasket or loose bolts are usually the cause.

11. Fast acceleration after prolonged low-speed driving can produce a hard, glassy brown coating on the insulator tip and electrode. Glaze is conductive and can ruin plugs.

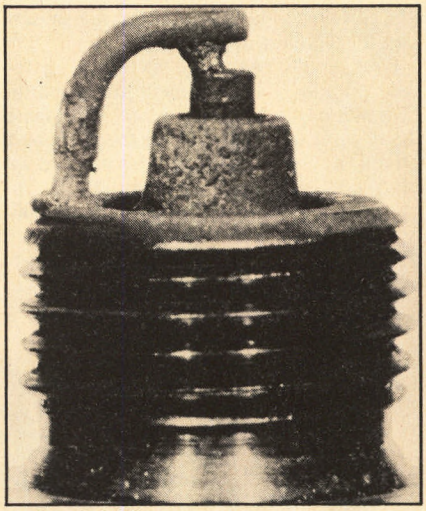
12. If you were to cut away the outer shell of the plug, this is what a dirty insulator would look like. Sandblaster will remove this.



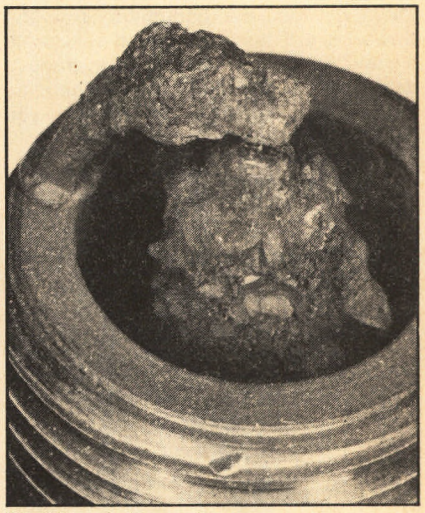
7. Champion Gap Tool



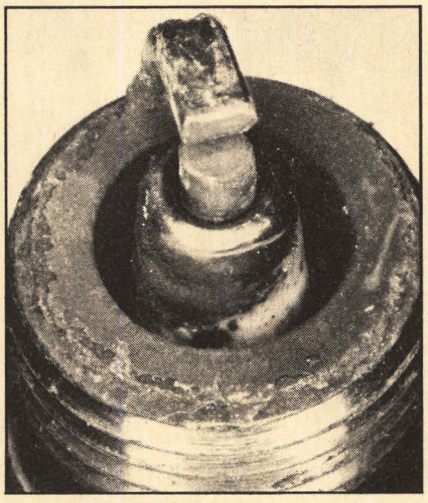
8. Core Bridging



9. Gap Bridging



10. Silicone Deposits



11. High-Speed Glazing

12. Carbon Fouled Plug

wire with "poly" or "vin" in their trade names. Some of these are transparent and look good on show cars, but their polyvinyl chloride insulation melts easily near a hot exhaust manifold. A silicone rubber insulation is used on cables designed for maximum heat resistance. Belden 7770, Autolite 7SH, and cables sold under the generic name "7SH" in speed shops are examples. They will usually operate continously at 450° F. without failure.

All cars now use resistance type high tension cable, but some of it isn't very resistant to internal breaks and burnouts. The conductor is usually a nylon or glass fiber string impregnated with carbon—at least on production cars.

If you're careful to pull on the plug connector and not the wire when removing the cables from the spark plugs, the factory installed resistance cable can last a long time. However, many resistance cables have a soft "fluffy" conductor which fails to provide good contact for the terminals. The result is often a tiny spark which arcs between the carbon impregnated yarn and the terminal. The heat eventually burns away the conductor and produces an ignition failure.

Because of burnouts and breaks caused by careless handling, resistance cable has gotten a bad name with many car owners. It should not be replaced with metallic conductor cable, however—for the sake of your spark plugs and the neighbors' TV. Instead, replace the factory cable with one of the reliable brands of resistance cable.

If for some reason you must use metallic conductor cable, it's necessary to add resistance to the stock ignition system if you are to avoid rapid spark plug gap growth due to electrical erosion. The usual method is to use plug connectors with built-in resistance or a "lump" type resistor at the distributor cap. These are available from radio shops. The use of resistor plugs will do a half-way job on solving the problem.

Lump resistors come as little plastic tubes with screws in each end. Cut the wire (metallic wire only) between the secondary coil and distributor and screw one in place. You can also buy resistors that go on each spark plug, but their durability, in our experience, has not been too good. Several companies now sell magnetic suppression wire, which has very low resistance, but excellent

suppression. Whittaker makes wire sets with lump resistors in each plug connector, attached to metallic wires. That way the wires are more durable, but you still have the resistance built in.

All wires, whether metallic or resistance types, should be checked with an ohmmeter. If the resistance of any one wire is above 40,000 ohms, suspect a bad wire. But before you condemn it, measure a new wire of the same type for comparison. Resistance specifications for wire vary several thousand ohms, depending on the manufacturer. While checking with the ohmmeter, flex the wire to see if there are any breaks in it. If the ohmmeter jumps to infinity, there is definitely a break. Don't worry about an increase of a few thousand ohms as you flex the wire. That's normal with carbon-string wires.

You may wonder why the new car makers continue to use carbon string wire when all the aftermarket companies are promoting other types of resistance wire. The main reason is that carbon string wire is the only type that provides maximum suppression. The other wire designs have good suppression, but they don't quite keep the interference level down to what you get with carbon string wire.

SPARK PLUGS

Often termed the barometer of engine condition, the spark plugs have one main function: to fire properly under all normal engine operating conditions.

The art of "reading" a plug to determine engine operating efficiency is also covered in the tune-up chapter, but as part of the ignition system alone, there are certain tell-tale points that are important to "lighting the fire."

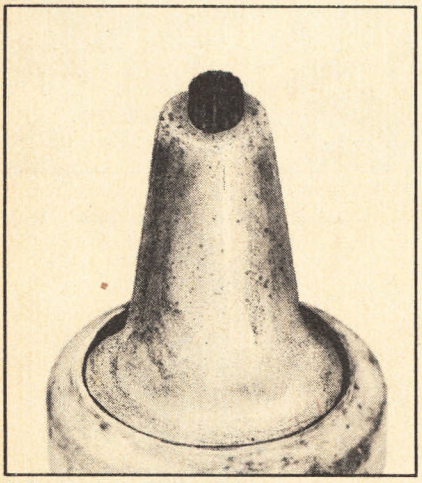
First, you'll need the correct plug for your engine. This is usually just a matter of walking into the parts store and telling them what kind of car you drive. They'll check a chart prepared by the spark plug company and give you the right plug—hopefully. Mistakes are occasionally made, so it's important to know a bit about spark plug design to protect yourself from accidents.

It's impossible to put an 18mm (thread diameter) plug into a 14mm hole, but a plug with the wrong *reach* could be installed. Reach refers to the length of the threaded portion of the plug shell. Always check the reach of the new plugs against that of the old. Installing a plug with a ¾-in. reach in an engine made for ⅜-in. reach spark plugs could bend the valves or knock holes in the pistons. Installing a short reach plug in a deep hole won't cause mechanical damage, but it'll mean a definite power loss and very quick fouling or burning of the spark plugs.

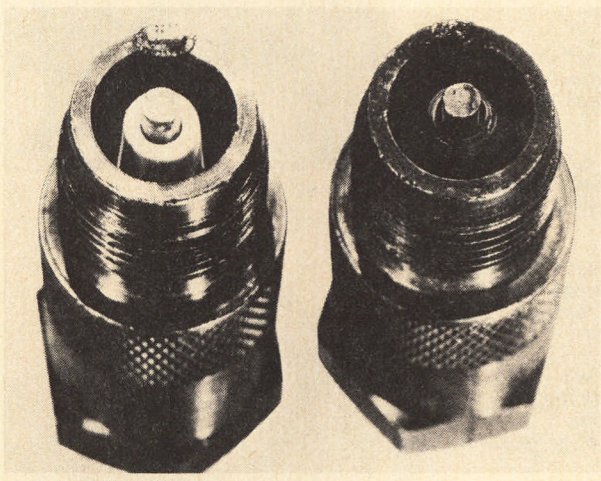
1. This plug insulator is not properly cleaned. A good sandblaster will remove all the deposits so that the insulator is white.

2. Detonation can not only ruin pistons, but also spark plugs. The ground electrode was snapped off clean by the force of detonation.

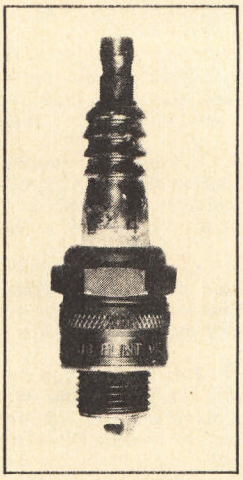
3. A dirty insulator top can cause flashover, and a dead cylinder. Clean upper insulator with a rag and solvent only, never sandblasting.



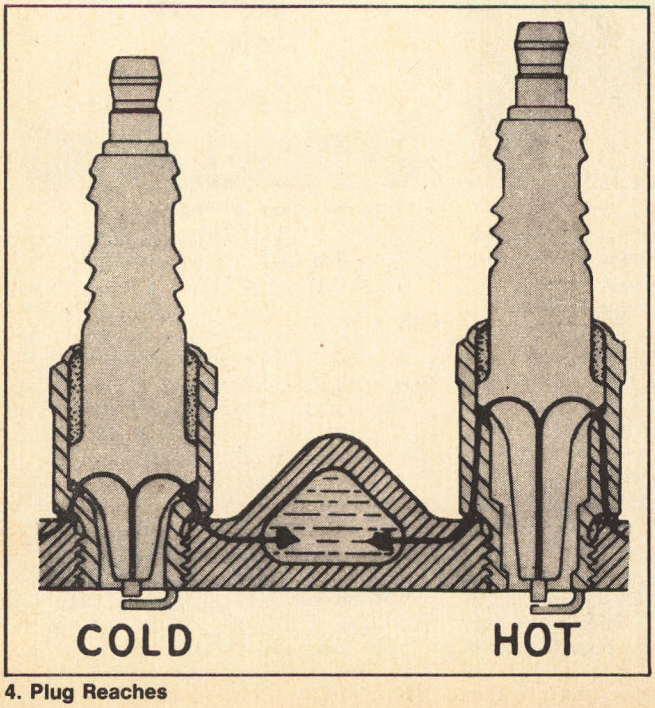
1. Improperly Cleaned Insulator



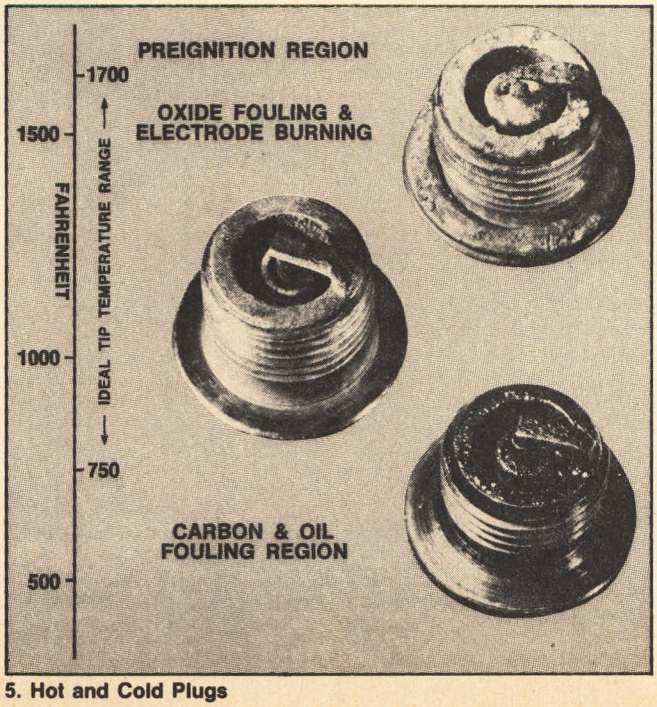
2. Detonation Damage



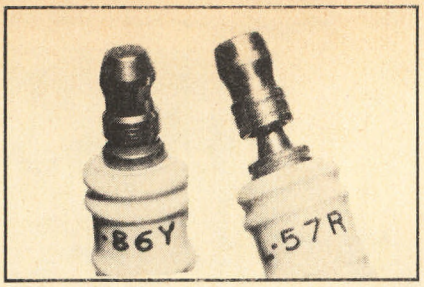
3. Dirty Insulator Top



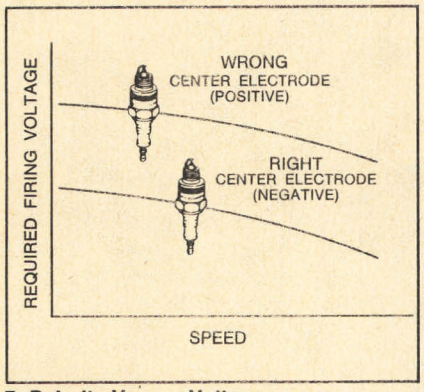
4. Plug Reaches



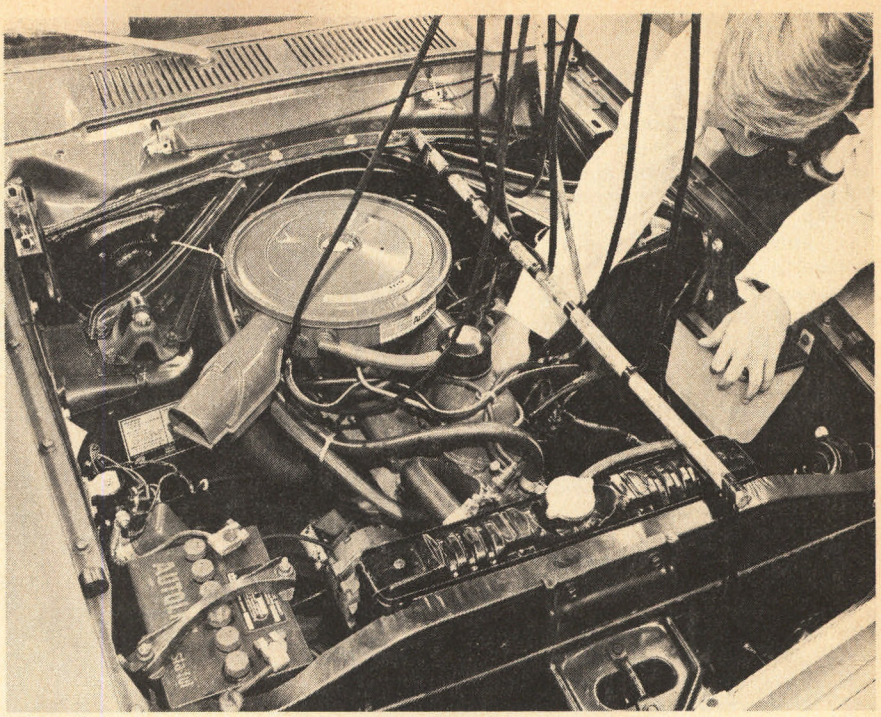
5. Hot and Cold Plugs



6. Top Types



7. Polarity Versus Voltage



8. Test Lab

4. The plug with the longer nose will run hotter because the heat cannot get to the cooling water as easily. The hot plug will stay clean longer, but it may burn up too.

5. Fouled plug at bottom is too "cold." Plug at top shows signs of overheating, with the possibility of preignition damage. Condition of plug in the middle shows proper heat range choice for particular use.

6. When selecting plug connectors, make sure they'll fit the plug you intend to use. Some connectors require that the terminal nut be taken off, as is possible with plug at right. Terminal at left is solid.

7. Wrong coil polarity requires a higher voltage to fire the plug, and a greater chance for misfire. Plug should have negative polarity.

8. In the Champion Spark Plug lab, a wire leads to each plug for exact temperature readings. Engine vacuum and spark timing are also read.

It is also imperative that a spark plug of the proper heat range be used. If a plug is too "cold" for your engine, it will not retain enough combustion chamber heat to burn fouling deposits off its firing end. If the plug is too "hot," it will retain excessive combustion chamber heat. This can be extremely dangerous. Not only do overheated plugs wear out quicker, but they may become incandescent and ignite the fuel/air mixture in the cylinders before the spark actually fires. This is called preignition and, if sustained, can destroy pistons or even an engine.

You can tell whether a plug is of the proper heat range by comparing its number to those recommended for your car. Looking at the length of the insulator nose will tell you comparatively little regarding heat range these days due to the many other variables in spark plug design. If it's not the right number, don't use it. The exception being when it is a different brand that, therefore, has a different number, but is listed for your car by the spark plug manufacturer.

A final factor to be considered when changing plugs is gap style. There are two popular types used in cars today. The first, called *standard gap,* is the traditional plug design with its ceramic insulator nose wholly contained within the plug shell. The second type, called *projected nose,* is actually in wider use among car makers than standard gap plugs. Its insulator nose extends beyond the end of the threaded portion of the plug shell.

Both standard gap and projected nose plugs may be listed as alternatives for your car in the spark plug manufacturer's chart. If so, pick the projected nose type even if it costs a few cents more. They'll give better fouling resistance and increased power in most engines—although, in some cases, the spark may have to be retarded a few degrees to eliminate excessive "ping." Don't use projected nose plugs in engines for which they are not recommended—especially in flathead powerplants or those with highly domed pistons. There's a chance that the valves or piston crown will strike the plug nose. Plugs with platinum or other fine wire electrodes and surface gap plugs having no side electrode should not be used unless specified by the car manufacturer.

Used plugs that have been operating at the proper heat range and whose electrodes are not badly eroded or burned, can be filed and regapped after cleaning and will give added satisfactory mileage. The spark will jump from a sharp edge on the center electrode more easily than from a rounded, worn electrode. Put the spark plug shell in a vise, then bend the ground electrode out of the way and file the center electrode flat and sharp with a small file. Blow all the filings out, and set the gap with a round wire gauge. If the insulator was previously sandblasted clean, you will now have new-plug performance from your old plugs. Always do the sandblasting before you file the electrode, because the sand will take away the sharp edge. Also, sandblasting or cleaning solvent are the only ways to clean plugs. Wire buffing wheels on a bench grinder are definitely out, because the wire wheel leaves metallic tracks on the porcelain that cause misfiring. Never adjust plug points by applying pressure to the center electrode, as damage to the insulator tip will result. Bend only the side or ground electrode when setting gap.

When installing new spark plugs, do not take their gap settings for granted. Sometimes the same plug will be used on different engines with different gap settings. So you must check the gaps to see if they are set for the engine you are working on.

Care should be taken when installing plugs, new or used. Be sure that the cylinder-head plug holes are cleaned and free of dirt or carbon particles both at the gasket seat and inside the threads. Plug threads should also be clean, undamaged, and lubricated.

Screw plugs in finger-tight against the gasket, then go an additional ¾-turn with a plug wrench. If you aren't sure of your ability to tighten plugs correctly, use a torque wrench. Folded gaskets, the type that screw on the plug threads, do not require a torque wrench, even when they are reused several times. Tapered seat plugs are another story. They don't use gaskets, and they can stick tighter than the government's grasp on a tax dollar if you tighten them too much. Check the tapered seats in the head, use a good torque wrench to tighten them, and by all means *believe* the wrench. You are not doing yourself a favor by going a few extra foot-pounds, as you will find out when you try to take them out a few thousand miles later.

On some Chrysler Corp. engines, the

plugs are mounted in long tubes and no plug gasket is used. The tube should be checked for burred edges and cracks in the plug mounting area. If any engine has an aluminum head, always inspect the plug threads with a jeweler's magnifying glass for any plug thread irregularities, and reject those with burred threads. A bad thread can quickly destroy the threads in an aluminum head and require that a Heli-Coil insert be installed to save expensive repairs or replacement.

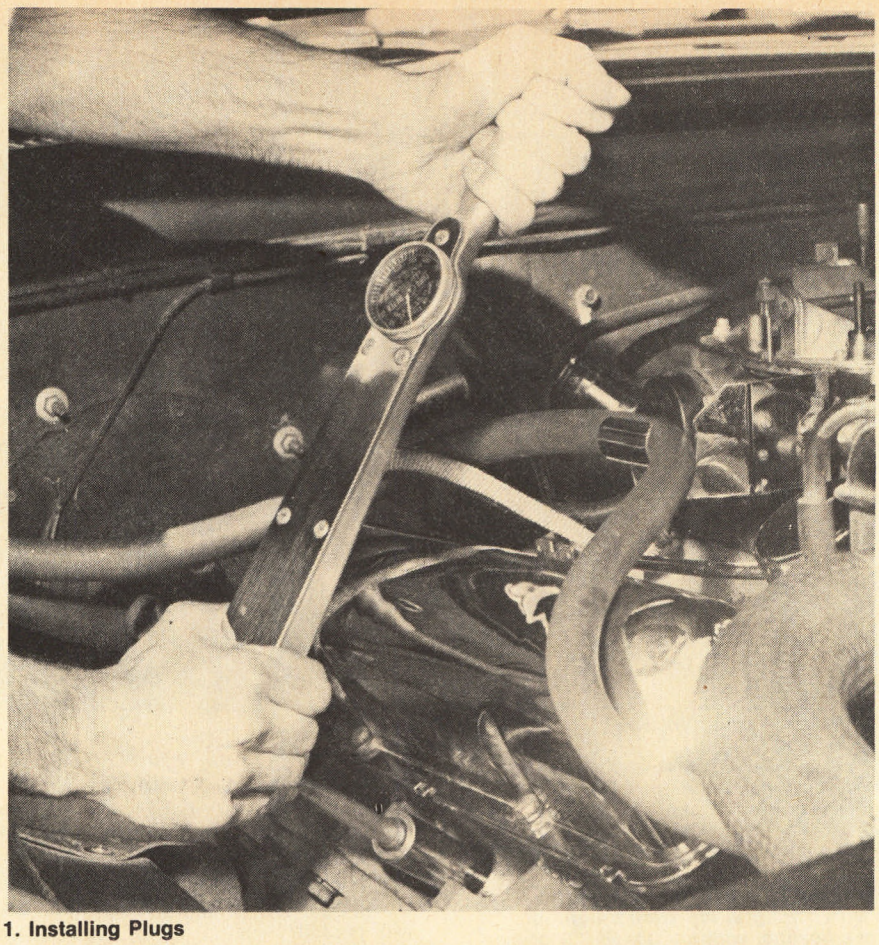
RESISTOR PLUGS

Originally designed for the old flat-head-6 Chryslers to allow wider gaps, which then gave a better idle, resistor plugs are now available for almost any car. If your engine has metallic wires, resistor plugs will help reduce gap growth.

Resistor plugs of 5000 ohms are standard equipment on late GM cars, which also use resistor wires. Before both resistor wires and plugs were used together, the resistance value of the plugs was 10,000 ohms. Champion makes both values: the 10,000-ohm with an R prefix, and the 5000-ohm with an X prefix. Theoretically, you should use the 5000-ohm plug with resistor wires, and the 10,000-ohm plug with metallic wires. But you can pair them up the opposite way, and it won't have any effect on engine operation. Other plug makers appear to have dropped their 10,000-ohm plug and are making only the 5000-ohm model.

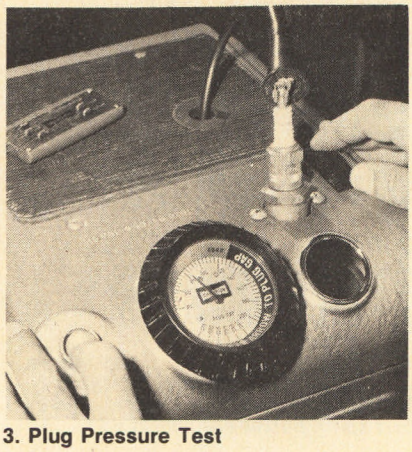
SERIES GAP PLUGS

Series gap plugs, which have an internal air gap that the spark must jump before reaching the electrodes, are gaining wide acceptance among car owners. They have the ability to clean themselves quickly of fouling deposits accumulated in low-speed, stop-and-go driving when "opened up" on the freeway. It takes time for spark voltage to rise to the level required to jump a plug gap. If the plug is fouled, conductive deposits may drain off enough voltage before its peak is reached to cause a misfire. By forcing the spark current to jump an internal

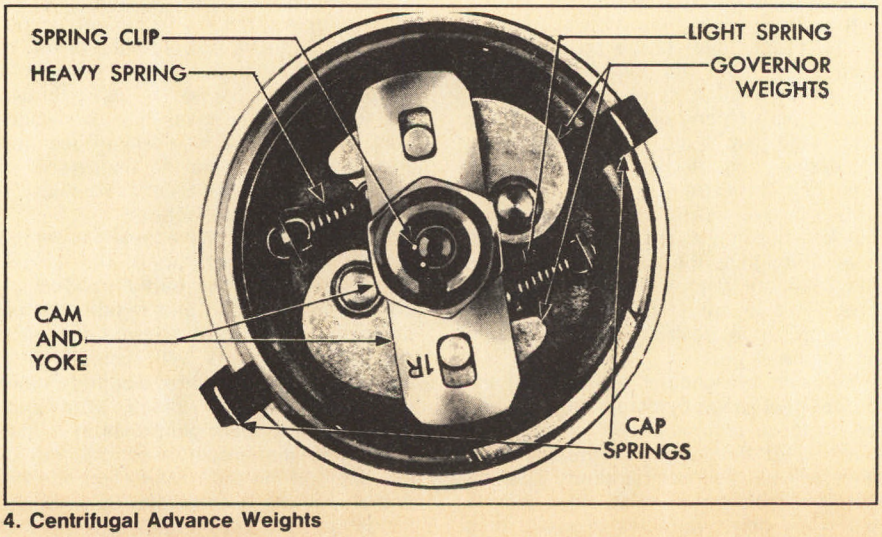


1. Installing Plugs

2. Sandblasting Plug



3. Plug Pressure Test



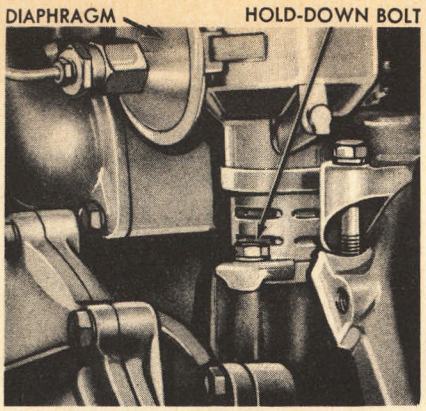
4. Centrifugal Advance Weights

1. When it comes to tightening plugs, the torque wrench is best, but if you don't have one, then tighten the plugs from ½ to ¾ of a turn after you get them finger-tight.

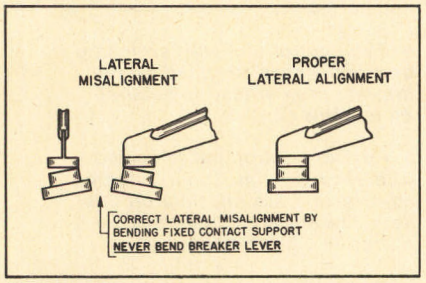
2. Wobbling the plug while cleaning is important. It allows sand to get into all parts of plug and remove carbon particles.

3. Air pressure test is interesting, but the only real test of a spark plug is its operation in an engine. Inspection with magnifier is good, too.

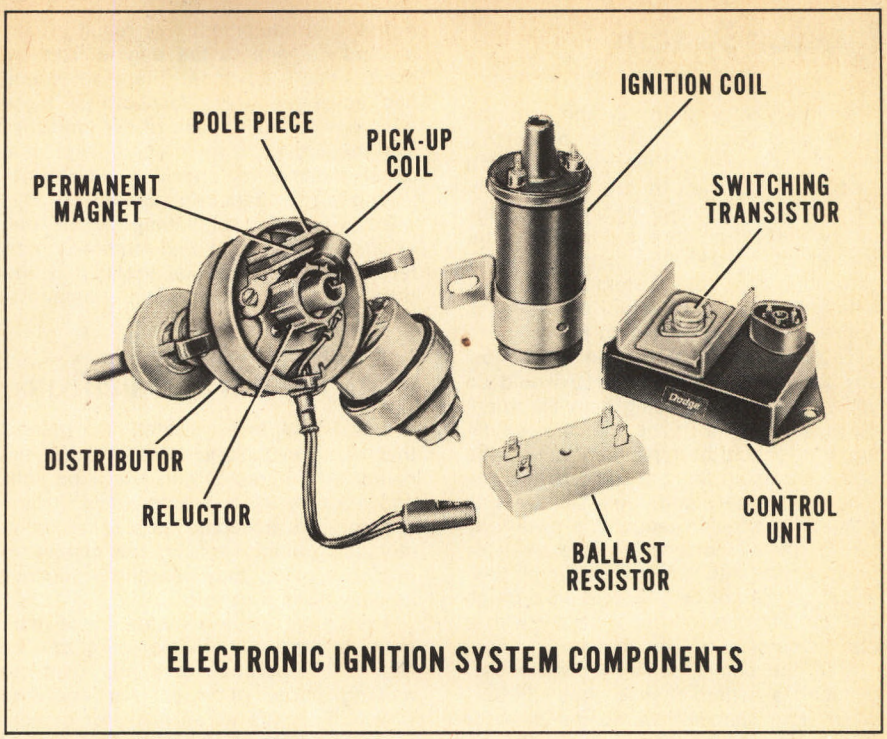
4. In a distributor with the weights below the plate, pins on the weights engage holes in the cam yoke. As the shaft increases its speed of rotation, the weights fly out against spring tension and the pins advance the cam's position on the shaft.



5. Distributor Hold-Down Bolt



6. Point Alignment



7. Chrysler Electronic Ignition

5. To actually remove the distributor, simply disconnect the vacuum advance line, take off the primary wire and distributor cap, and loosen the hold-down bolt. On most cars, the distributor can be lifted out after the bolt is removed.

6. Bad alignment shortens point life considerably, and the result in operation will be a poor spark because of insufficient point contact.

7. Chrysler Corp. has gone to the electronic (transistor) ignition system with its 1973 models. Available on some 1972 models, the EIS includes a pointless distributor for minimum maintenance.

gap first, it is certain to be at full voltage before ever arriving at the firing electrodes.

TESTING SPARK PLUGS

The best advice we can give you here is to forget it. There is no way to test spark plugs outside an engine, unless you own a million-dollar laboratory. The air pressure "plug tester" used in many garages is merely a way to pacify car owners who ask for a plug test. We like the plug tester, not for "testing" plugs, but for showing the action of the spark on a fouled plug, and for demonstrating spark action between the electrodes. Plug testers don't really test plugs because they are at room temperature, and the combustion chamber in the engine is at several thousand degrees. A visual inspection of plugs will tell you more than any tester. The inner porcelain should be clean, and the center electrode should be square and sharp, with the proper gap.

DISTRIBUTOR TYPES

There are three basic distributor systems in use on late-model American passenger cars: the conventional coil-condenser-contact point, the point-controlled transistor, and the pulse-controlled transistor. All are a combination of engine-driven rotor and electrical or mechanical switching, whose function is to deliver a usable spark.

CONVENTIONAL DISTRIBUTOR

Distributors, whether conventional or transistorized, are driven by a gear on the engine camshaft. The distributor shaft drives the breaker point cam and the rotor. Because the gearing of the distributor shaft is in time with the engine, care must be taken when replacing to see that it is in the correct position. The simplest way to do this—after disconnecting all wires, removing distributor cap, and loosening mounting clamp—is to mark outside of case for reference to a similar mark on engine block, then slowly withdraw distributor without turning it. As it is pulled out, the rotor will turn slightly as the helical gears disengage from the cam gear.

When it is completely disengaged, mark the rotor in reference to a similar mark inside distributor housing. Aligning these reference marks before reassembling will put the timing close enough that you should be able to fire up the engine, provided the engine crankshaft has not been turned while the assembly was out of the engine block.

The timing of the spark to the stroke of the pistons must be varied in relation to speed and load conditions. Timing is adjusted automatically by the distributor's internal spark advance system. Most distributors employ two forms of spark advance—a centrifugal mechanism that advances or retards the distributor cam in relation to the distributor drive shaft, and a vacuum diaphragm which advances or retards the position of the breaker point assembly relative to the distributor cam. Most Volkswagens and certain other economy cars use only the vacuum controlled automatic advance mechanism.

Most cars being built today have dual chamber vacuum advance units to reduce exhaust emissions at low speeds. These can be identified by the two vacuum lines leading to the diaphragm chamber on the distributor. An important exception is to be seen on recent big engined Chrysler products. This distributor uses an electrical solenoid to retard the spark at idle or during certain types of low-speed driving. It can be identified by the plastic "box" on the side of the distributor which houses the retarding solenoid.

Ignition points are made of very hard, tough tungsten alloys but are subject to wear and spark erosion, and they require periodic replacement. They control both the low-voltage saturation of the coil when closed, and the release of the high voltage when they open. It is important that they are erosion free and mate as perfectly as possible to ensure total contact. The time the points are closed is called dwell or cam angle and will vary according to point gap.

Wide point gaps open slowly, causing excessive arcing and burning; and the wider the gap the shorter the dwell, which causes insufficient coil saturation and a missed spark (or maybe a whole bunch of missed sparks and an engine that won't run). If too close, the points are snapped open, and have a tendency to bounce. A close gap gives more dwell, but the points don't separate enough to give a clean collapse of the primary, and we have a misfire.

Point systems used on some cars have two sets of points connected so that the primary current flows when either set is closed. The points are staggered so that one set opens before the other, with the spark occurring when the second set opens. Because of the staggered position, the first set closes before the other, increasing the dwell for more spark in-

tensity at high rpm.

Another wear point is the rubbing block, a phenolic or plastic block that wears very well if there is a slight amount of lubricant in the form of light oil or a sparing smear of grease on the cam whenever points are checked or replaced. Many distributors have an oil-saturated wick for lubricating the rubbing block, and this should be changed, not re-oiled, when replacing points.

You can buy a "point file" in almost any auto parts house, but you would do yourself a favor by using it to file spark plugs, not points. If the points need filing, they should be replaced. Line up the point surfaces as we indicate in the tune-up chapter, and then set the gap either with a feeler gauge or a dwell meter. Don't ever attempt to gap worn or pitted points with a feeler gauge. A feeler gauge will not be accurate on a rough surface. Worn points must be set with a dial indicator or a dwell meter.

With new points, some mechanics recommend a setting that is about .003-in. wider than specified to compensate for the initial rubbing block wear. This is usually not necessary if the rubbing block lines up with the cam.

Make sure the rubbing block is resting exactly on the tip of the breaker point cam when you set point gap with a feeler gauge.

Tampering with the centrifugal or vacuum advance mechanisms without the proper test equipment may result in permanent damage to the engine from incorrect spark advance. There are specified advance curves for both of these functions for each make of car, and they are available to mechanics with test bench facilities for checking out and adjusting to manufacturers' specs.

Rebuilding for such things as bearing or shaft replacement also requires expert techniques and special tools; it is impractical for the occasional home mechanic to attempt.

POINT-CONTROLLED TRANSISTOR DISTRIBUTOR

Transistors—those mysterious "things" that have revolutionized electronics, miniaturized our radios and television sets, and are now used in automotive ignition systems—are accepted as a rather commonplace component, yet few people really know what they are and what they actually do in a circuit.

Transistors are a combination of man-made crystalline materials which can be likened in operation to a relay with no moving parts, or a current operated switch. They act as an insulator or non-conductor until small amounts of current are applied to the proper segment, then they become highly conductive and capable of carrying large amounts of current.

They are used as a master switch (instead of the points) to trigger the coil saturation and collapse; the points are used to control the very low voltage nec-

1. Delco's one-piece points/condenser unit was its 1972 improvement, but its replacement cost was challenged by government and Delco withdrew the unit from the market.

2. The unitary Delco points/condenser went into a standard window-type distributor. Now with replacement points/condenser units off the market, owners have to replace the distributor breaker plate to install standard condenser.

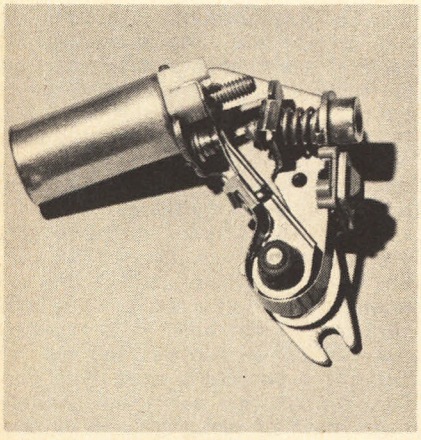
3. A reluctor (1) replaces the traditional cam in Chrysler's Electronic Ignition. The magnetic pickup assembly includes a pole piece and permanent magnet (2) and a pickup coil (3) and performs the functions of a set of contact points.

4. The control unit with switching transistor (1) is mounted on the firewall. Plug-in lead is secured by a screw (2).

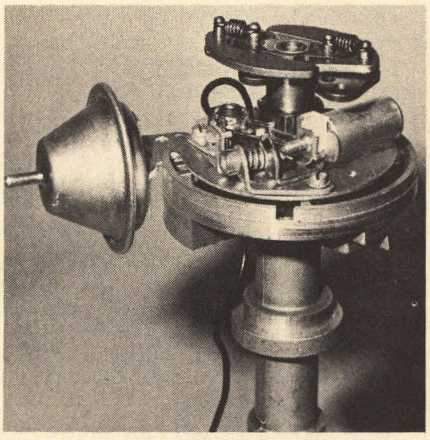
5. Rear of control unit is sealed with epoxy-like material. Since no adjustments are possible on this item, the entire unit must be replaced if it gives trouble.

6. Normal ignition uses a single resistor; Chrysler EIS uses a dual ballast resistor mounted on the firewall and connected to the system by plug-in leads.

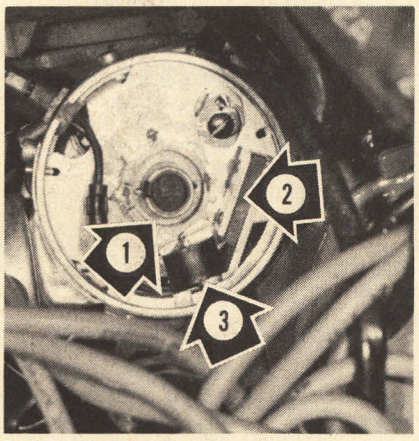
7. You can adjust the point gap on this Delco-Remy "window" distributor while the engine is running, either with or without a dwell meter.



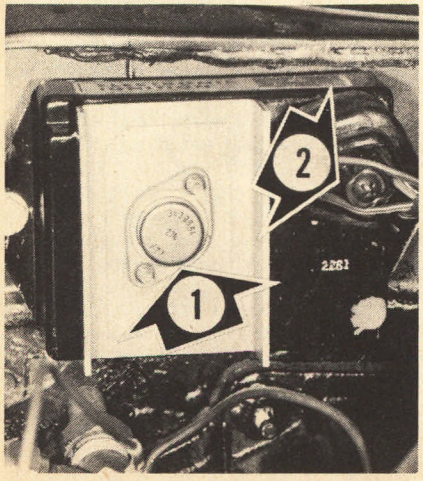
1. Delco One-piece Unit



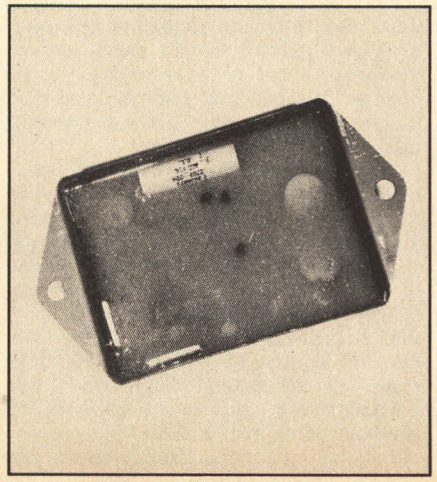
2. Distributor Breaker Plate



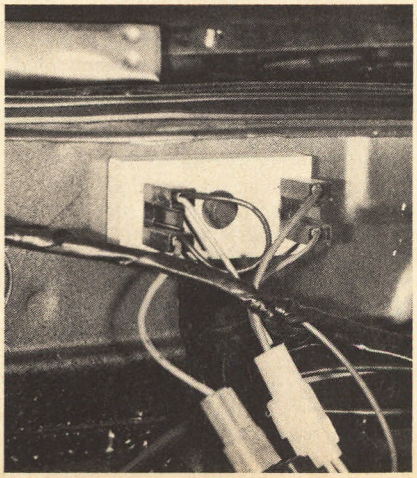
3. Chrysler Electronic Ignition



4. Control Unit



5. Sealed Control Unit



6. Dual Ballast Resistor

essary to make the transistor act as a higher voltage switch. As a result, the points are handling much smaller amounts of current than with a conventional system. Arcing, and the need for a condenser to reduce it are eliminated, increasing point life considerably.

Because of the very rapid flow of current, there is no appreciable time lag, and timing procedures and advance adjustments are the same as with conventional systems. Transistors are sensitive to heat and other electronic breakdowns and should be checked for shorting if the ignition fails to fire.

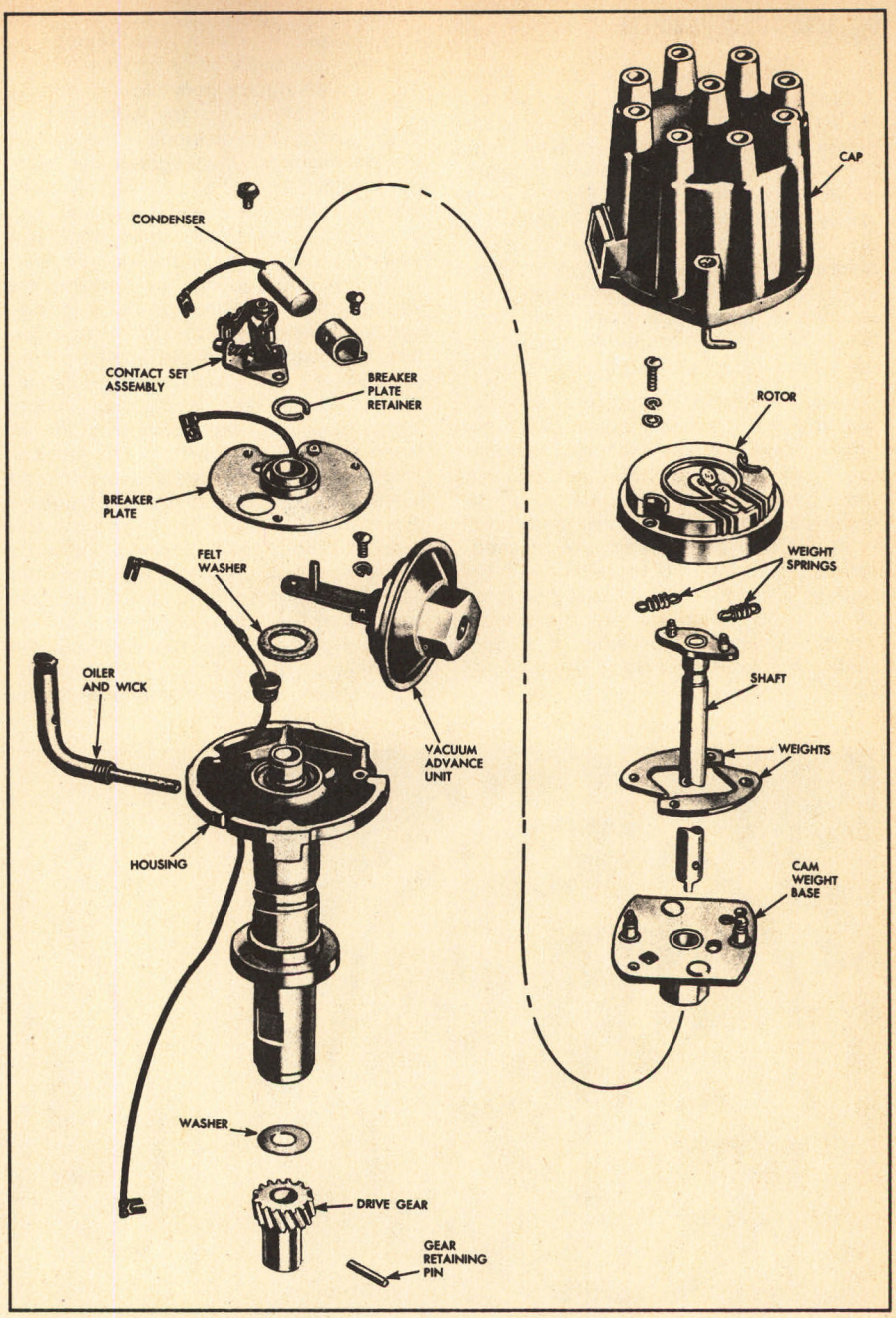
Heat sensitivity is partially controlled by mounting the transistors in a finned case or heat sink. This alone is not enough protection if the unit is placed where severe engine heat can reach it. On stock, factory-installed transistor systems, never change location of the heat sink. When installing optional transistor systems, mount in coolest part of the engine compartment.

Points do have to be checked but only to compensate for rubbing block wear, which, after the initial break-in, should stay stable for about 20,000 miles. Be very careful not to use an oily feeler gauge, since even the lightest film on the points can cause trouble with the low voltage carried by the contacts in a transistor system. Coils and transistorized ignition systems are slightly different in their primary windings from standard ones. It is recommended that only coils made for these systems be used, since adding only the transistorized switching unit with standard coil could shorten life of both parts, in addition to reducing the efficiency of the transistor operation.

PULSE-CONTROLLED TRANSISTOR DISTRIBUTOR

Used in some GM and all 1973 Chrysler products, the Electronic Ignition System is a highly sophisticated version of the point-controlled transistorized ignition in that all switching is done electronically. There is no rubbing block wear and no point gap to maintain, ensuring long and uniform operation. Both vacuum and centrifugal advance mechanisms are used to compensate for varying engine speeds and loads in much the same manner as conventional point distributors.

Internal construction consists of a rotating pole piece in place of the breaker point cam. This has the same number of equally spaced lobes as the number of engine cylinders. This rotates inside a magnetic pickup assembly which takes the place of the breaker plate/contact point assembly. This magnetic pickup is composed of a permanent magnet made of ceramic material, a pole piece, and a pickup coil. The stationary pole piece, like the rotating pole piece, has equally spaced internal lobes or teeth, one for each cylinder of the engine. This magnetic pickup, located in the lower section of the distributor housing, is moved by the vacuum diaphragm to control vacuum advance. The rotating pole piece is coupled to the centrifugal advance mechanism, providing spark control compensation for engine speed. A rotor tops the whole internal assembly and



7. Window-Type Distributor

acts as the high-voltage distributor to the individual spark plugs.

As the distributor internal components rotate, the teeth in the rotating pole piece line up with the internal projections on the permanent magnet pole piece, causing an induced current in the pickup coil. This current is sufficient to trigger the transistors in the ignition pulse amplifier circuit, resulting in coil saturation, release of coil high voltage to the distributor, and proper distribution to the spark plugs. Because of the rather complicated circuitry in the pulse amplifier system, it is recommended that it be tested only with the proper equipment and by qualified ignition experts. A mistake in polarity, or high voltage reaching low-voltage segments of the circuits, can result in permanent damage to the transistorized circuit.

The pulse amplifier unit has no moving parts, and exclusive of the permanent lubricated bearings in the distributor, there are no rubbing or contacting parts that require adjusting to compensate for wear. A periodic check of both primary- and high-voltage wiring and both advance mechanisms should be all the maintenance required for the pulse-controlled transistor ignition system.

DISTRIBUTOR INSTALLATION

When installing a distributor that has been removed from the engine without being marked, it is important to establish an initial timing setting. For this operation it is necessary to line up the timing marks on the flywheel or vibration dampener in relation to the compression stroke of No. 1 cylinder.

Since modern auto engines are not equipped with provisions for handcranking, a remote starter switch or someone blipping the starter switch in the car will be necessary to get the timing marks coordinated with the compression stroke.

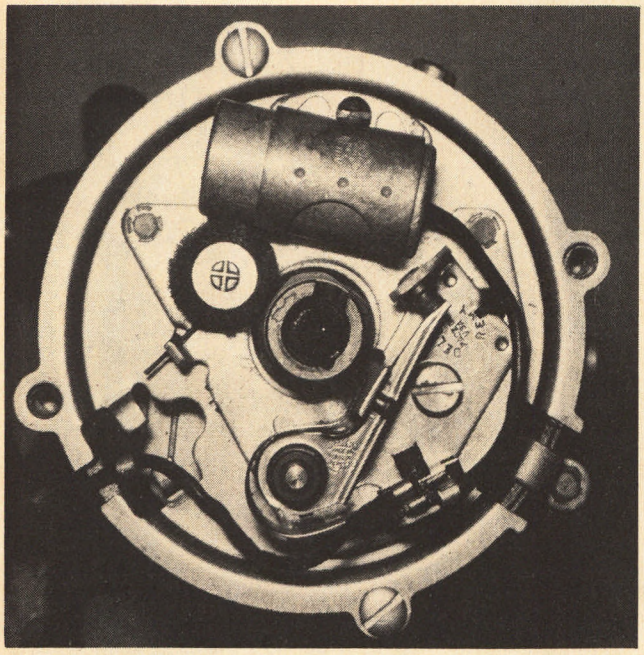
Remove spark plug from No. 1 cylinder. For deeply recessed plug access on

some Chrysler Corp. engines, a compression gauge is almost a necessity. Hold thumb over plug hole or observe gauge while blipping starter switch, noting pressure buildup which will indicate piston is coming up on compression stroke. Watch for timing mark which indicates the proper number of degrees before top dead center for ignition timing. Some vibration dampers have calibrations on either side of top dead center, so be sure the engine is stopped on the factory recommended timing mark.

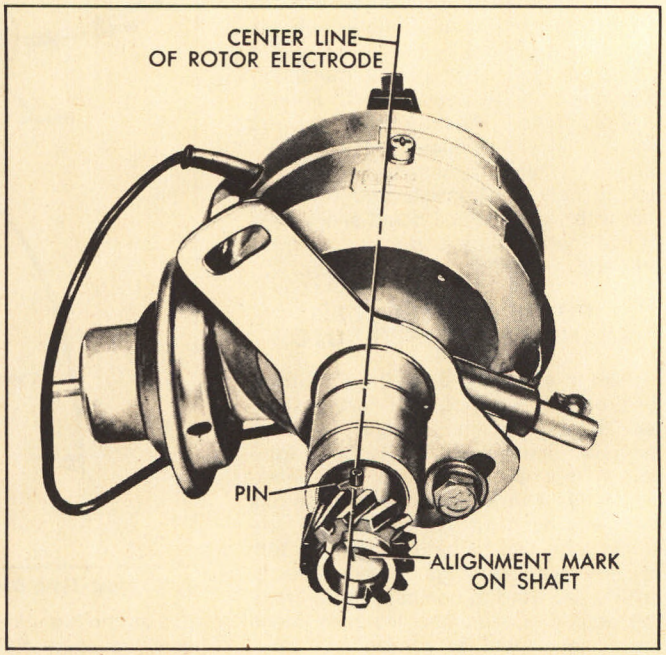
Install distributor so that rotor lines up with the No. 1 cylinder spark plug lead on the cap. Ease the assembly down into the block mounting hole and engage lower gear with the one on camshaft. As these gears are helical, the distributor shaft will turn as the teeth are meshed, naturally causing the rotor to turn. Be sure to allow for this and set the rotor off just enough before inserting assembly into block hole so that when it is fully seated, the rotor is in No. 1 cylinder position.

Install the distributor mounting bolt and clamp, but leave it loose enough so that the distributor body can be turned. Turn the distributor body slowly opposite to the direction that the cam rotates. Stop turning the distributor the instant the points open, then tighten the hold-down bolt and your engine will be timed close enough to allow it to run. You should only have to turn the distributor a very small amount. If, before you start turning it, the rubbing block is on the wrong side of a cam lobe (closing side instead of opening side), then when you turn the distributor to the point opening position, the rotor will no longer be under No. 1 segment in the cap. If this happens, you are probably one tooth off. Remove the hold-down clamp, lift the distributor until the gears demesh, and move the shaft one tooth in whichever direction you need to go. Then move the distributor body to the position where the points are just opening. The important part of this procedure is determining exactly when the points open. You can do it with a piece of tissue or cigarette paper between the points. The paper will come loose just as the points separate. A better way is to use a test light connected to the distributor primary terminal and ground. If your test light does not have a battery in it, turn the ignition switch on and the test light will be off while the points are closed. When the test light comes on, you will know the points have opened. If you have a battery-powered test light, then disconnect the primary wire from the distributor and connect the test light to the distributor primary terminal and ground. The light will be on when the points are closed and will go off the instant they separate. Remember that you turn the distributor body opposite to the direction that the cam rotates.

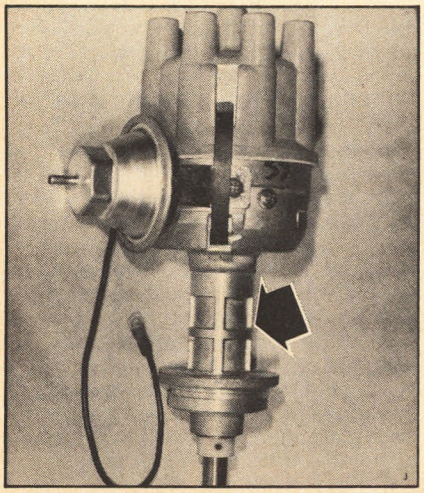
After tightening the hold-down clamp, check to be sure the points are just opening, and that the rotor tip is under the No. 1 segment in the cap. If, no matter what you do, the rotor and point timing won't check out, then you may have one of those rare cases of a distributor that is assembled wrong. There have been some cases where a cam that is pressed onto the shaft has slipped, making it impossible to set the point and rotor timing correctly. The engine may run,



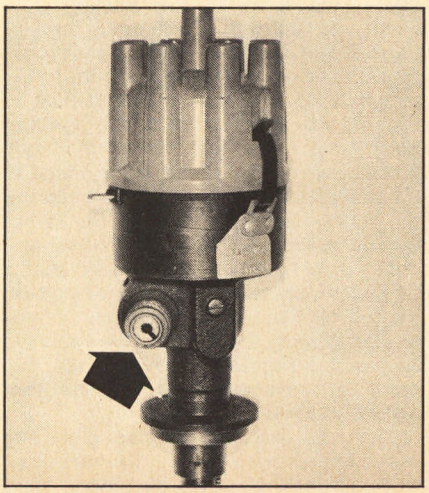
1. Delco-Remy Distributor



2. Chrysler Distributor



3. Chrysler Distributor Housing



4. Dual-point Distributor

1. Delco-Remy 4- and 6-cylinder distributors have greasy mesh to lubricate cam. Note arrow on top of shaft to indicate rotation.

2. Chrysler Corp. distributors are quite conventional and easy to repair. It is very important to reassemble the gear, shaft and rotor in their correct relationship for proper distributor positioning.

3. Chrysler Corporation distributors are quite conventional and easy to work on. The housing of Chrysler distributor is aluminum; waffle pattern gives housing added strength.

4. Dual-point Prestolite unit was used on Chrysler high-performance models. Housing is cast iron instead of aluminum. Some models of the dual-pointer came with tach drive, but fit only Chrysler engines.

but not very well because the rotor is between two segments and the spark sometimes goes to the proper cylinder and sometimes to the wrong one. Your chances of finding this condition are extremely rare.

Static timing should always be followed by a timing light check with the engine running. When using a timing light, the vacuum hose must be taken off the distributor and plugged. Remove and plug both hoses on cars with double chamber advance units. Chrysler products with solenoid controlled distributors should have both the vacuum hose and solenoid wire disconnected. Always remove the solenoid wire from the carburetor, not the distributor. This prevents accidental shorts and damaged wiring.

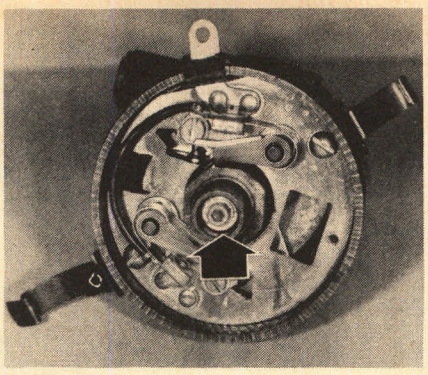
Before replacing cap, examine it as well as the rotor for cracks. Very often undetected damage at these points can cause trouble not apparent in circuit test procedures.

CAPACITOR-DISCHARGE IGNITION

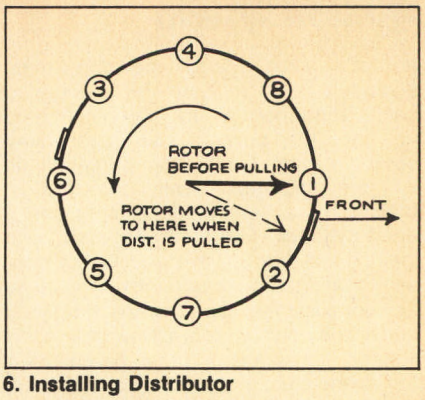
Transistor ignitions came on the marketplace with a big splash. It seemed as if everybody was making one. It also seemed as if every garage had one lying in the corner somewhere that they had taken off because it didn't work right. Transistor ignitions were pretty much of a failure because the transistors were so delicate. All you had to do to blow the things was to pull the wire out of the coil and crank the engine. The tremendous buildup of voltage would back up and blow one or more of the transistors.

Capacitor-discharge ignitions are admittedly a type of transistor design but they are considerably better and a heck of a lot tougher. A transistor ignition uses the same old method of collapsing the coil field to create the secondary spark. The capacitor-discharge or C-D ignition uses an entirely different method. It charges up a capacitor which then is triggered by either points or a pulse control distributor so that the capacitor fires a charge through the coil primary. Because the capacitor kicks about 250 volts into the coil's primary windings instead of the 6 or 12 volts of a conventional ignition, the result is one heck of a spark that does the job a lot better than either transistor or conventional ignition systems.

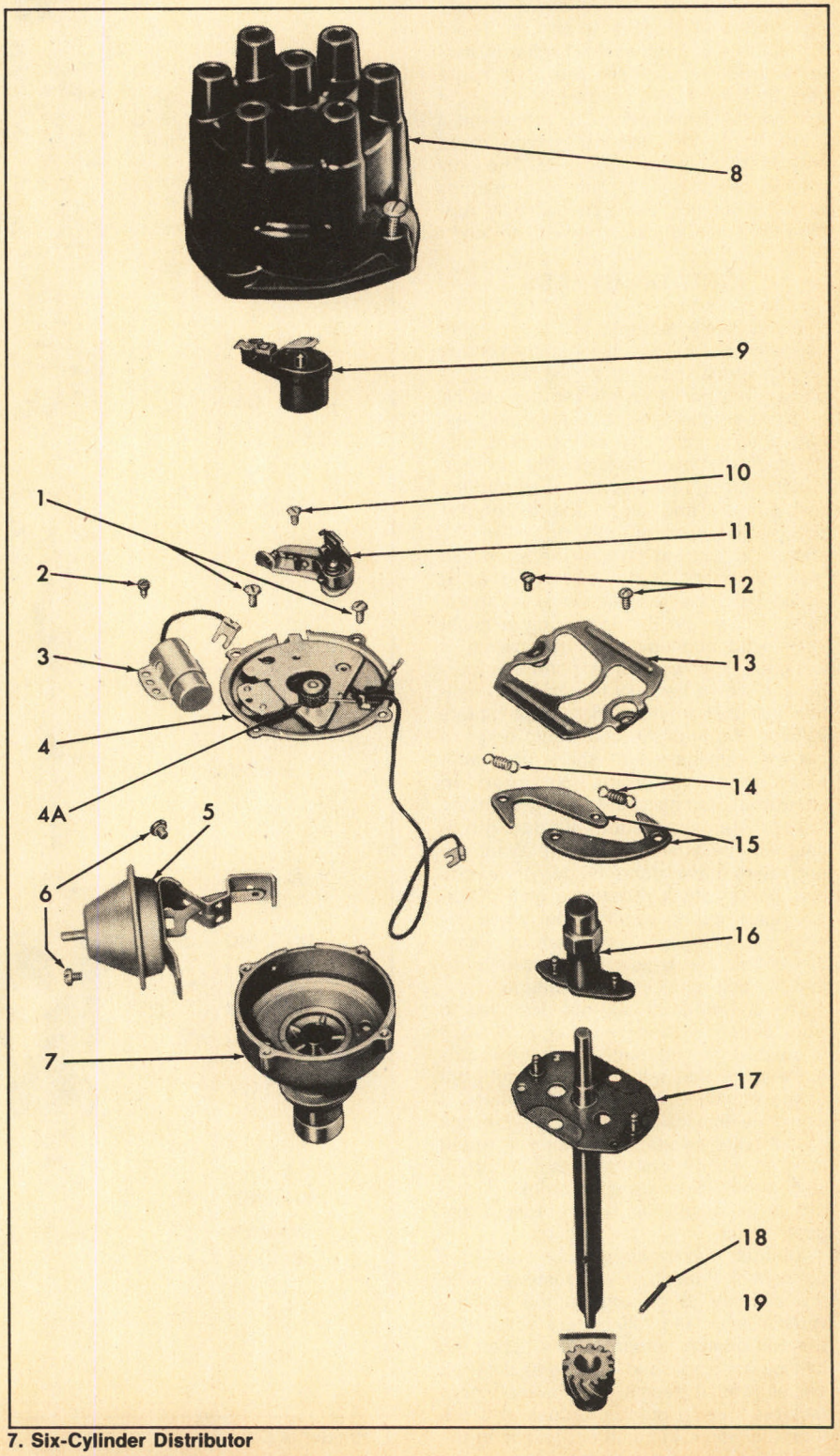
One trouble with conventional ignitions



5. Adjustable Cam



6. Installing Distributor



7. Six-Cylinder Distributor

5. Seldom-seen feature of Prestolite dual-point distributor is an adjustable cam. Timing can be altered without loosening the distributor body in block by loosening Allen screw in center of the shaft and moving cam. Engine must be dead if this method is used.

6. The rotor may turn as the distributor is withdrawn from the engine. Note its final position. When reinstalling the distributor, place the cam in this same position and it should turn back to its original position as the cam and distributor gears engage.

7. This is a typical Delco 6-cylinder distributor having both centrifugal and vacuum advance systems.

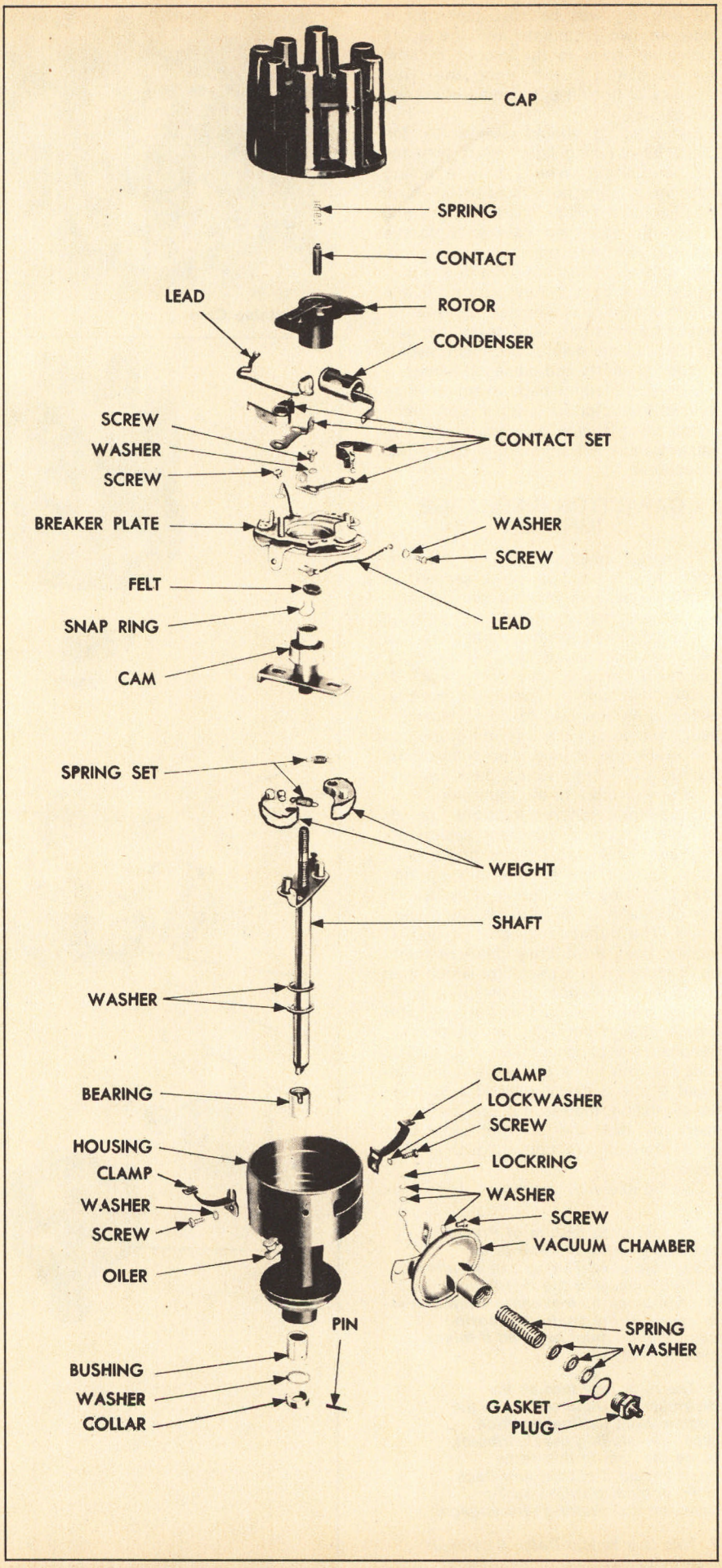
is that it takes a long time to build up enough voltage to jump the spark plug gap. During the time that it is building up voltage, the current can leak away across a dirty spark plug porcelain so that the plug never really does fire. In that case we have a fouled plug and a dead cylinder. The capacitor-discharge ignition will fire spark plugs that a conventional ignition could never hope to fire because the capacitor-discharge ignition does not rely on a slow buildup of voltage. It zaps the coil and the coil zaps the spark plug, right now, so that there is no chance for any leakdown of voltage that would cause a misfire. There are some good capacitor-discharge systems around but there are also some very bad ones, just as bad as some of the old transistor systems. If you spend a lot of money for a special ignition, make sure that you get a good one. The only way to be sure is to talk to somebody who has already been successfully running the same ignition you want to buy.

IGNITION BYPASS

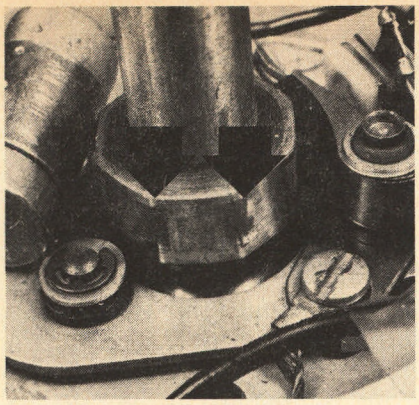
It may seem strange, but the ignition coil does not receive full battery voltage during normal running of the engine. A primary resistor is inserted in the circuitry between the ignition switch and the battery terminal on the coil. Current from the battery flows through the ignition switch, through the resistor, then into the coil primary and on to the distributor points. The resistor cuts down on the amount of current flow in the circuit so that the spark is not as strong as it would be if the resistor were not there. Cutting down on the spark output might seem kind of stupid, but the system is designed that way for a particular purpose. It would be easy to design an ignition coil that would work on full battery voltage. But then the coil would only put out the same strength spark no matter what conditions were. We need an excessively strong spark during cranking to get the engine started, but during running we don't need as much. What the engineers have done is design a coil that works with a resistor to give a normal spark during running, but when the engine is being cranked there is a special circuit that bypasses the resistor so that the coil receives more voltage.

The coil was actually not designed to work under full battery voltage. When it is operated on full battery voltage it puts out a spark that will knock you right out of the engine compartment. However, it would be impossible to operate the coil on full battery voltage very long. It would burn up. So the coil receives full battery voltage only during engine cranking, and this is accomplished with a special bypass circuit.

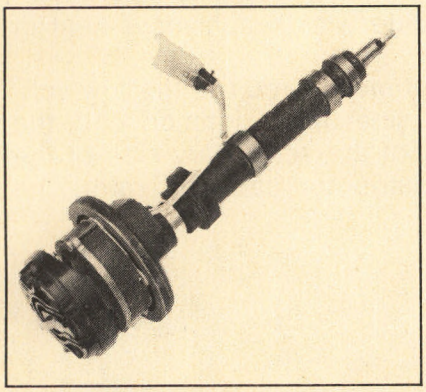
All that the bypass amounts to is a connection that is made somewhere in the circuitry to go around the primary resistor and feed full battery voltage to the coil primary terminal. This bypassing can be accomplished at several different places, and it seems as if every manufacturer tries to put his bypass in a different location. In some cases it is in the



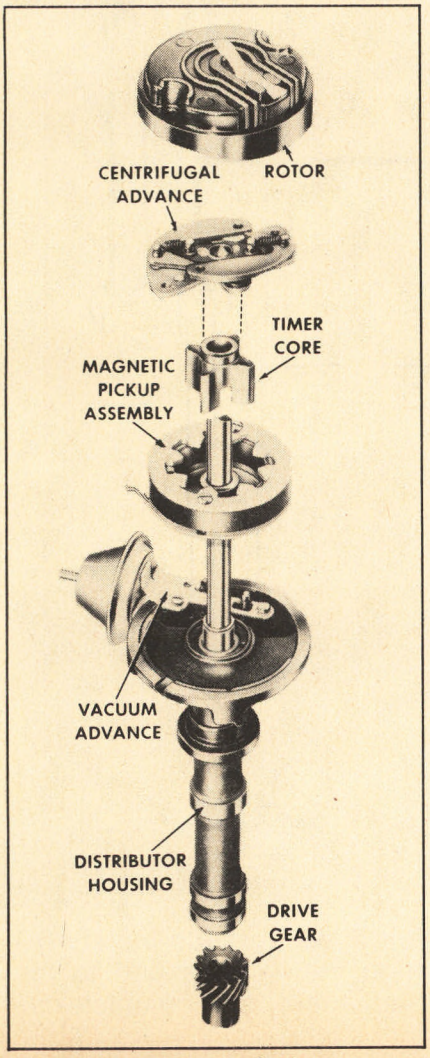
1. Prestolite Dual-Point Distributor



2. Worn Distributor Cam



3. Breakerless Distributor



4. Breakerless Advance System

1. Chrysler has used the Prestolite dual-point distributor on some of its high-performance models. This unit differs from the Ford dual-point unit in that it has both vacuum and centrifugal advance.

2. Here are the results of not using the proper lube on a distributor cam. Not only has the rubbing block worn down, but cam is also badly worn.

3. Breakerless (no points) Delco-Remy distributor was option on some GM cars. It is used with a separate amplifier to fire the coil.

4. Breakerless distributor has same vacuum and mechanical advance parts as normal distributor. Magnetic pickup moves for vacuum advance.

ignition switch, with an extra pair of contacts that shunt full battery voltage to the coil. Of course this only happens when the key is in the start position. When the driver lets the key come back to the run position, the extra pair of contacts is disconnected and the coil receives its battery voltage through the primary resistor. Another place for bypassing is at the solenoid on the firewall. When the solenoid plunger moves to make contact for the large amount of current that flows direct from the battery to the starter, it also contacts a small finger that sends battery current to the ignition coil through a separate wire. On General Motors cars the ignition bypass is in the starter-mounted solenoid. A little finger in the solenoid makes contact and sends full battery voltage through a separate wire that connects with the coil primary terminal.

The resistance itself may be either in the form of a wire wound around a ceramic insulator and mounted on the firewall or near the coil or, in the case of Delco systems, a resistance wire between the ignition switch and coil. If the car starts but stalls as soon as the key is turned from the "start" to "run" position, it may be that this wire is burned out. Connect a jumper wire from the hot side of the battery to the small coil terminal that's not connected to the distributor. If the engine keeps running you'll know that the resistance wire is shot.

SPECIAL IGNITION ACCESSORIES

Beware of the carnival pitchman who demonstrates the marvel ignition intensifier. These gimmicks are by and large resistance-increasing bits of metal, air gaps, or coils that do produce a hotter spark. However, they are disgracefully over-priced. Series-gap or resistor plugs do the same job for only pennies more than standard plugs.

A stock ignition system, properly maintained and adjusted for the engine it is designed for, will give excellent service for a long time. As the requirements for more intensity occur, accessory components from reliable makers are valuable.

Spark cables with silicone rubber insulation should be used where unavoidable proximity to the exhaust headers requires extra heat protection. Solderless plug connectors such as the Rajah terminal ends have been and still are the mark of well maintained ignition systems.

Spark plugs are no exception to the "something for nothing" pitch exploited by exaggerated advertising claims. Plugs from reliable manufacturers are the result of extensive and expensive research and development, and none will compensate for a poor ignition system or a worn-out engine. Special racing plugs are available for a wide variety of reach lengths and thread diameters, and because of their wire-type electrodes, require special tools for changing the gap. When buying such plugs, make sure that the proper gapping tools are included in the purchase.

MAGNETO IGNITIONS

Basically, a magneto is an engine-driven linear alternating current generator combined with a system of distributing the generated voltage to individual spark plugs at the proper time. Linear means that the faster it is driven, the more voltage it produces. This has a distinct advantage with high-speed engines but some disadvantages at low speeds. Provision for spark advance in early mags was strictly manual, and their use confined largely to racing cars that were push-started.

As automotive competition spread from pure racing cars with special engines built just for the purpose, to drag and stock car events—and the hot rod enthusiast began extracting more and more performance from modified passenger car engines—the need for high-performance ignitions was obvious. Names like Joe Hunt, Harmon-Collins, Bendix, and Scintilla Vertex were added to the list of brand name speed equipment. Joe Hunt was making Offenhauser engine mags out of aircraft units before he devised a vertical magneto that replaced the standard automotive distributor. He still is a distributor for the Vertex, and sells more of those than anything else. He goes through each new Vertex, too, so he knows they are right when you get them. Harmon-Collins, now known as the Cirillo Super-Mag, developed a similar unit, and others are currently available from Mallory known as the Mini-Mag.

These vertical units are made to fit a variety of stock block engines, sliding into the regular distributor hole. Some use auxiliary coils or vibrators to provide the necessary starting voltage to the magneto, because mags do not provide their hottest spark at cranking rpm.

As stated earlier, high-performance distributors have largely filled the need for high engine performance on everything except the fuel-burning, supercharged race cars, but more than a few car owners still swear by the vertical magneto for their combination street-strip machines.

The modern magneto requires very much the same maintenance as a distributor. It has breaker points, mechanical centrifugal advance, and on some units, optional vacuum advance systems. In addition, these units are tailored more critically to engine requirements and are not just something one buys and sticks into the distributor hole of any old engine.

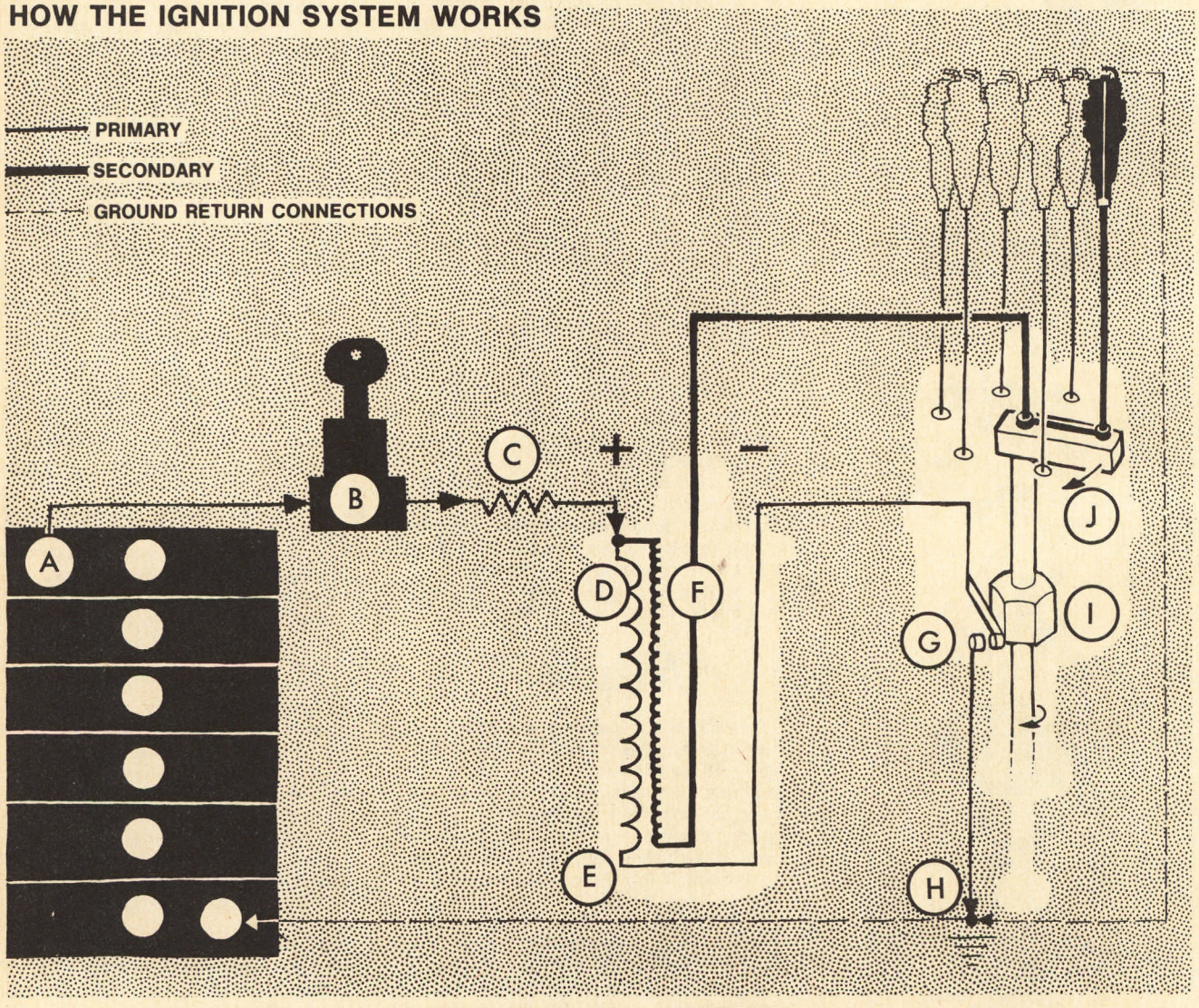
TROUBLESHOOTING THE IGNITION SYSTEM

This chapter deals with the ignition system. The operation of the ignition system is probably more critical to good engine operation than any other part of the engine. The strength of the spark needed to fire the air/fuel mixture compressed in the cylinders is approximately 20,000 volts. Just a small loss of spark strength will interfere with the normal operation of the ignition system and cause problems. The ignition system discussed in this chapter is the conventional battery/coil type which uses a set of breaker points in the distributor to control the timing of the spark. Transistorized and all-electronic ignition systems require several types of highly specialized test equipment to troubleshoot properly; therefore we will not go into them in great detail.

The ignition system performs two functions. First, it boosts the relatively low voltage of the battery to the very high voltage needed to fire the spark plugs. Second, it controls or "times" the exact moment of firing of each spark plug to coincide with piston movement in each of the cylinders.

This ignition system is broken down into two circuits. The primary circuit is the low-voltage side of the system and comprises the battery, the primary side of the ignition coil, the distributor points and condenser. The secondary circuit consists of the secondary side of the coil, the high-tension lead between coil and distributor, the distributor cap and rotor, the spark plug wires and the plugs themselves.

HOW THE IGNITION SYSTEM WORKS



When the ignition switch (B) is turned on, the electrical current flows from the battery (A) through the switch to the primary winding (D) of the coil, through the winding and to the distributor points (G). As long as the distributor points are closed, there is a complete circuit (H), allowing current to flow in the primary winding.

This flow of current produces a strong magnetic field in the coil which stays there until

something makes the current stop flowing. That "something" is the ignition points. The distributor, where the points are located, is gear-driven by the engine. There is a small cam (I) which opens and closes the points as the shaft in the distributor turns. Each time the cam opens the ignition points, the flow of current from the battery to the primary winding of the coil stops.

When the current flow stops, the collapse of the magnetic field around the primary winding induces a sharp pulse of high voltage in the secondary winding (F). This action is exactly like a power line transformer in reverse. The power transformer creates a low-voltage, high-current electricity for use in homes, and the ignition coil creates a high-voltage, low-current electricity to fire the spark plugs.

This brief pulse of high voltage is passed through the high-tension lead (the center lead in the distributor cap) of the coil to the distributor cap. Inside the distributor cap is a rotating contact (J—rotor) which transfers the pulse from the high-tension lead to one of the spark plug contacts inside the cap. Connected to the spark plug contacts are the spark plug wires and the spark plugs themselves.

Each time the distributor shaft rotates enough for the cam to open the points, the high-voltage pulse developed in the secondary of the coil is directed to the correct spark plug by the rotor and creates a strong spark across the tip of the spark plug to fire the air/fuel mixture inside the cylinder.

One important factor in the ignition is timing. Ignition timing means delivering the spark to the correct plug, and it must arrive at exactly the right moment for firing the compressed air/fuel mixture to produce the necessary power.

It takes a small but measurable amount of time for the ignited air/fuel mix to expand and create the pressure that pushes the piston down to make the engine run. This means that as engine speed (rpm) increases, the spark must come slightly earlier to allow time for burning to be well under way when the piston reaches top dead center (TDC).

There are several ways to accomplish this. All are known as ignition advance; that is, advancing the firing of the spark by a small fraction of a second. One such system is vacuum advance, which utilizes engine vacuum to make this change. The other system is mechanical advance, which uses a system of weights and springs in the distributor to advance the spark as the distributor shaft turns faster as engine speed increases. Most modern distributors use a combination of these two systems to create the correct advance for the engine.

TROUBLESHOOTING THE PRIMARY CIRCUIT

If the use of the ignition troubleshooting logic tree showed that there was a problem in the primary side of the ignition circuit, start by making a careful visual examination of all parts of the primary circuit: battery (A), coil (E), ballast resistor (C) if there is one, ignition switch (B), contact points (G) and all wiring.

The battery should be inspected for signs of corrosion around posts and connections. Battery cables should be looked at closely to make sure they are not corroded or broken. Insulation on all wires should be checked to see if there are any places where worn or frayed coverings might let wires short out against the engine or body. Heavy coatings of oil or grease can create a path for a shorted circuit. In some cars, a separate battery cable runs from the positive (+) post of the battery to provide current for the ignition system and other electrical parts. This will be a smaller cable alongside the heavy cable running to the starter. If this is broken or loose, the starter will crank, but no other systems will work. If no immediate problem can be seen, follow this list of individual troubleshooting steps for the primary circuit.

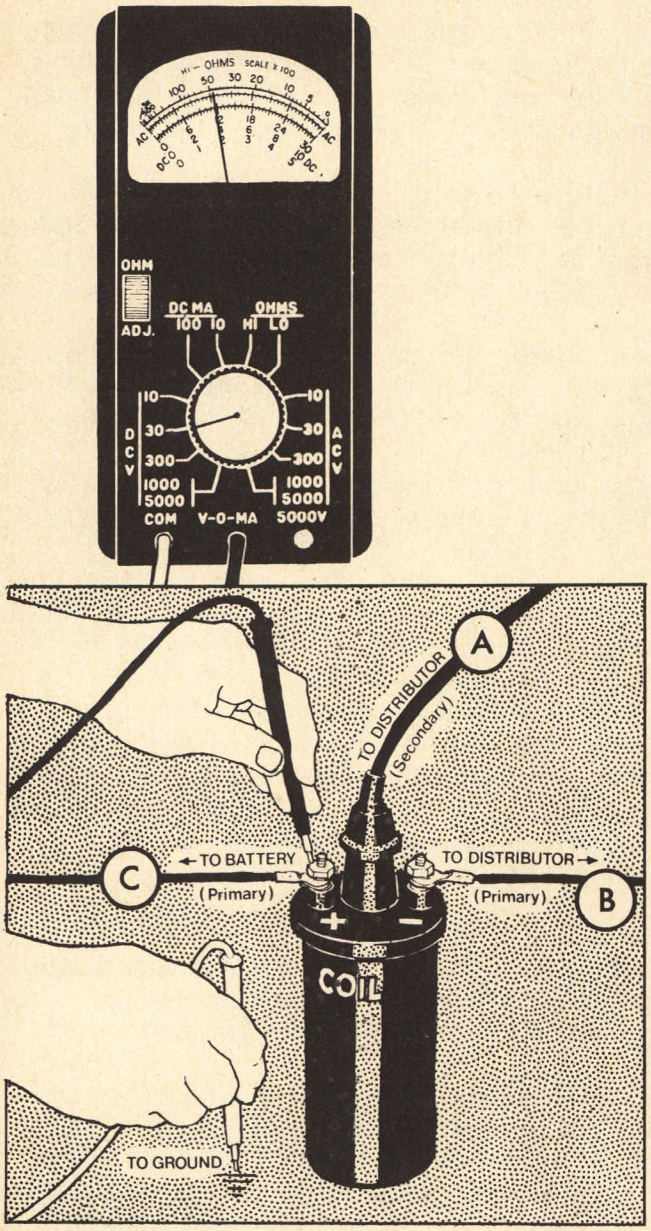
CHECKING THE IGNITION CIRCUIT

Unlike the starting system, the ignition switch supplies electricity to the primary circuit in two positions. In the "on" position, it supplies electricity through a ballast resistor or a resistance wire which lowers the voltage slightly to match the requirements of the coil. In the "start" position, when current is also being supplied to the starter to crank the engine, the ballast resistor or resistance wire is bypassed to increase the voltage on the coil and increase the strength of the spark. If the engine appears to start when the ignition switch is turned to start but dies as soon as the switch is released to the on position, there is something wrong with the ballast resistor or resistance wire circuit. Also check bulkhead or firewall plugs through which this wiring passes.

The quickest way to test the switch is with the multimeter. If the switch is hard to get at, you can make a quick check by making a couple of measurements on the coil.

TROUBLESHOOTING THE IGNITION SYSTEM

CHECKING BATTERY VOLTAGE AT COIL



In addition to the high-tension lead (A) coming out of the coil, there are two smaller connections. One connects the primary (+) side of the coil to the battery (C). The other connects the primary (-) side to the contact points in the distributor (B).

NOTE: ALL SETTINGS AND VOLTAGES USED IN THIS SERIES OF CHECKS ARE FOR 12-VOLT IGNITION SYSTEMS. FOR READINGS ON SIX-VOLT SYSTEMS, CHECK THE SHOP MANUAL.

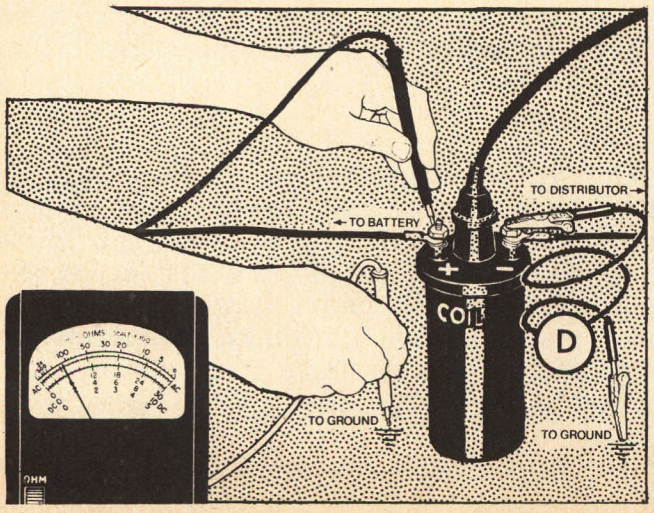
Isolate the coil primary (-) from the ground (B) either by removing the wire running from the coil to the points or by removing the distributor cap and cranking the engine until the points are open.

Connect one lead of the multimeter between the BAT (+) side terminal and the other lead to a good ground. Set the multimeter selector switch to read DC volts (direct current) at a range higher than 12 volts.

Turn the ignition switch to on. The meter should indicate 12 volts at the BAT (+) side terminal of the coil. If the normal voltage is not present, then the switch, the coil or the wiring between the battery and switch is bad.

NOTE: ALTHOUGH THIS READING IS TAKEN THROUGH THE PORTION OF THE WIRING THAT CONTAINS THE BALLAST RESISTOR OR RESISTANCE WIRING, IT DOES NOT MEASURE A CHANGE IN THE RESISTANCE OF THESE PARTS. TO COMPLETE A CHECK OF THIS CIRCUIT, PERFORM THE NEXT TEST.

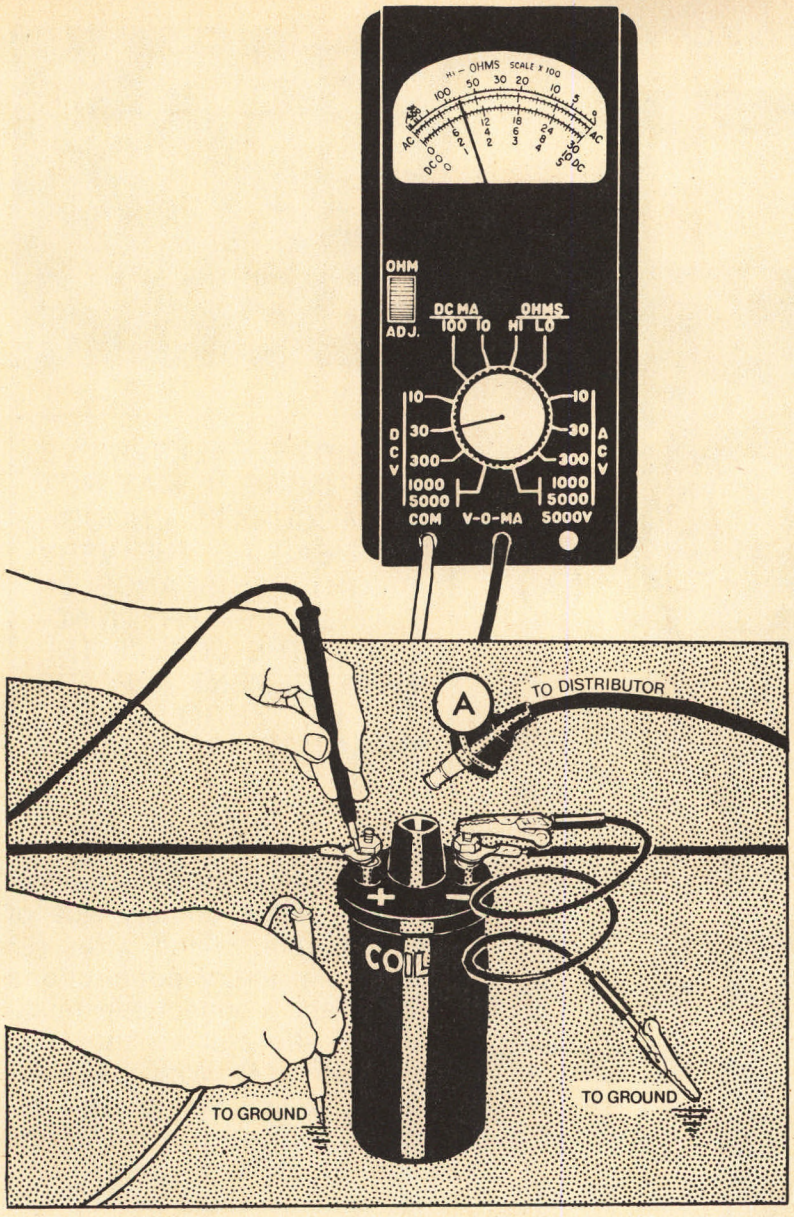
RUNNING VOLTAGE CHECK



Connect a jumper cable (D) between the distributor primary (-) terminal and ground. Leave the meter connected as in the previous check.

Turn the ignition switch to on. The voltage should be between 5 and 7 volts. If the voltage is lower than 5 volts, the ballast resistor or resistance wire may be faulty or there may be a loose connection between the coil and ignition switch or between the ignition switch and the battery. If there are more than 7 volts present, check the wire between the coil and the contact points. If you suspect the ballast resistor or resistance wire (one or the other will be installed in the primary circuit), check the shop manual for replacement instructions.

CRANKING VOLTAGE CHECK



This check sends current to the coil through the wire which does *not* contain the ballast resistor or resistance wire.

Leave the meter connected and the jumper wire installed in the same location as in the previous checks.

> **NOTE:** THE HIGH-TENSION LEAD (A) SHOULD BE REMOVED FROM THE COIL TO PREVENT CYLINDER FIRING.

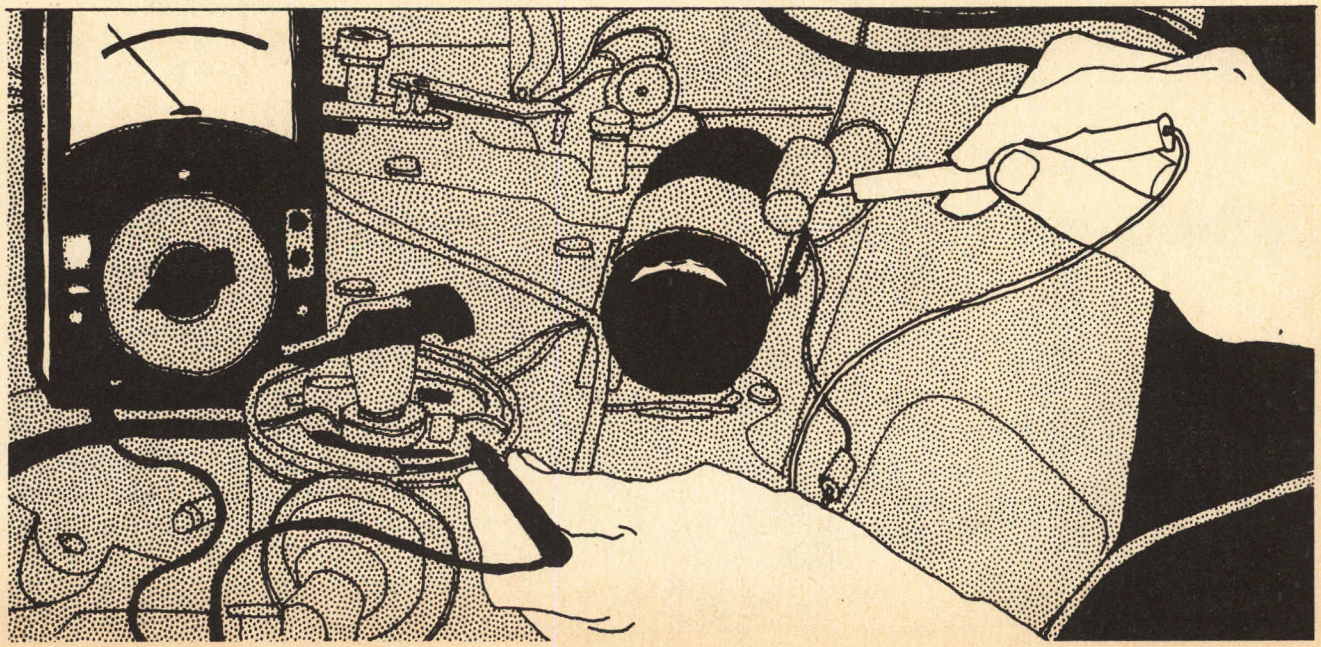
Turn the ignition switch to start.

The meter should indicate approximately 9 volts. (Ford automobiles will indicate approximately 7 volts.) The cranking voltage should always be greater than the running voltage reading in the previous test. If no voltage is present, check the ignition switch and the wiring in the cranking circuit.

If the voltage is low, nearly that of the running circuit, the starter may be drawing too much current or the battery may be weak.

> **NOTE:** SEE THE HIGH-RATE DISCHARGE TEST IN THE SECTION ON STARTERS.

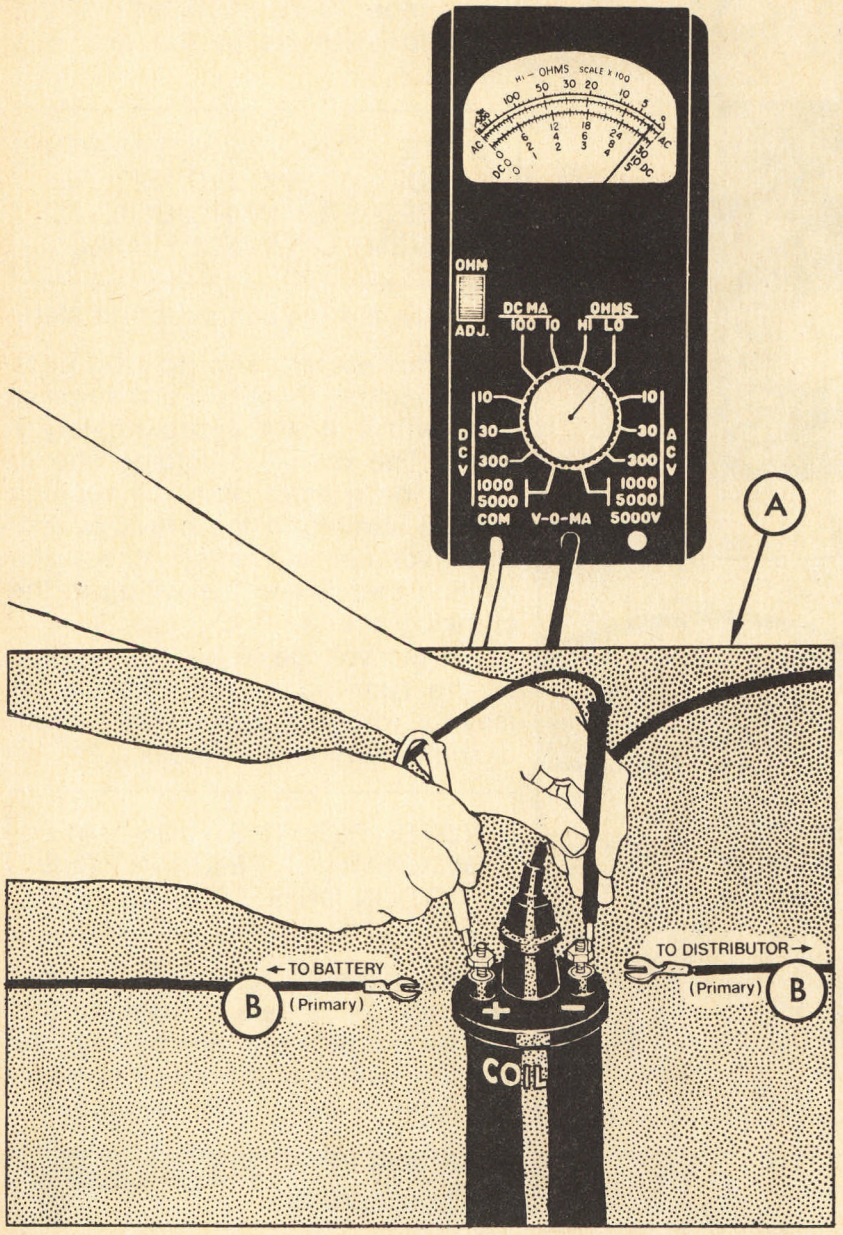
If all the primary circuit checks are good, it is safe to assume that the wiring between the battery, the ignition switch and the coil is good. The ignition switch is also good.



TROUBLESHOOTING THE IGNITION SYSTEM

PRIMARY WINDING RESISTANCE CHECK

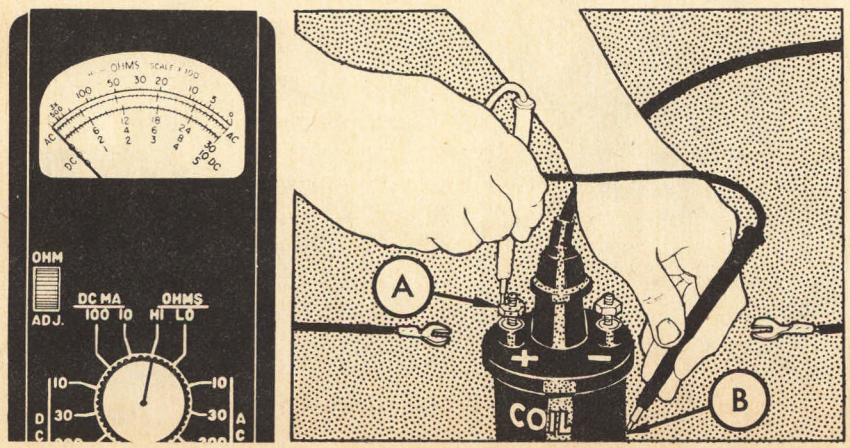
CAUTION: ALWAYS BE SURE THERE IS NO VOLTAGE IN THE CIRCUIT WHEN USING THE METER TO READ RESISTANCE. DISCONNECT THE BATTERY GROUND CABLE (-) TO AVOID DAMAGE TO THE METER



NOTE: INEXPENSIVE MULTIMETERS MAY NOT BE ACCURATE ENOUGH TO MEASURE THE VERY SLIGHT RESISTANCE OF A GOOD PRIMARY WINDING IN THE COIL. IF THE MEASUREMENT APPEARS TO BE ZERO OHMS, CHANCES ARE IT IS GOOD.

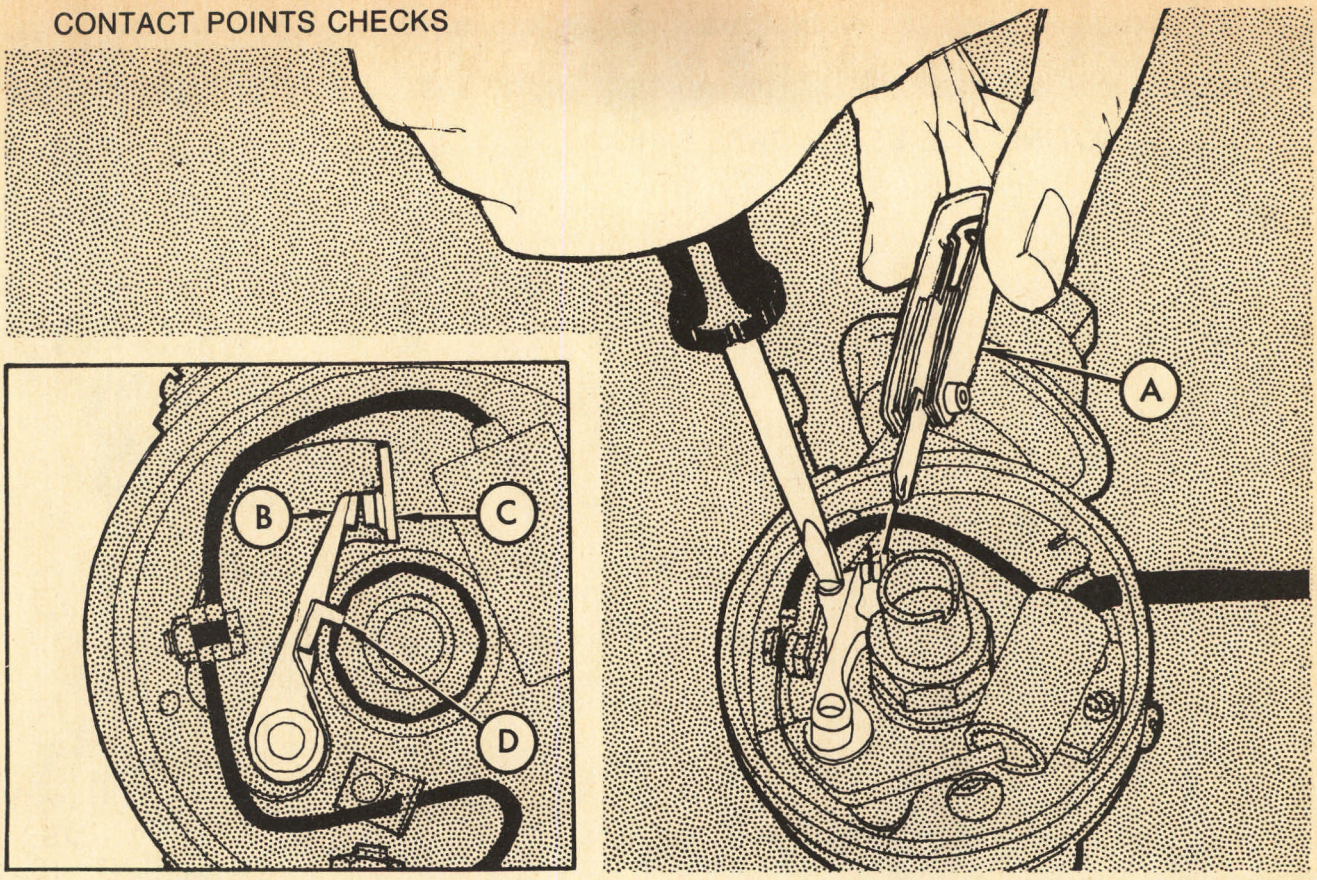
To check the internal resistance of the primary side of the coil, remove the wires (B) from the primary connections (+) (-) and connect the multimeter to the coil as shown in the drawing (A). With the meter selector switch set to read resistance (ohms), use the lowest range of ohms measurement. The reading should be approximately 1.5 ohms. If the reading exceeds 3.0 ohms, replace the coil.

PRIMARY LEAKAGE CHECK



Use the same test hookup as for the previous check. Set the meter selector switch to read the highest resistance range. Touch one probe (A) of the test leads to one of the primary terminals (+) or (-). Touch the other lead (B) to the case of the coil. This checks for a breakdown of the insulating qualities of the coil case. If the needle moves at all to read any other resistance than infinity, replace the coil.

CONTACT POINTS CHECKS



The contact points can be checked for operation in the ignition system logic tree, but there are several other conditions that can be looked for.

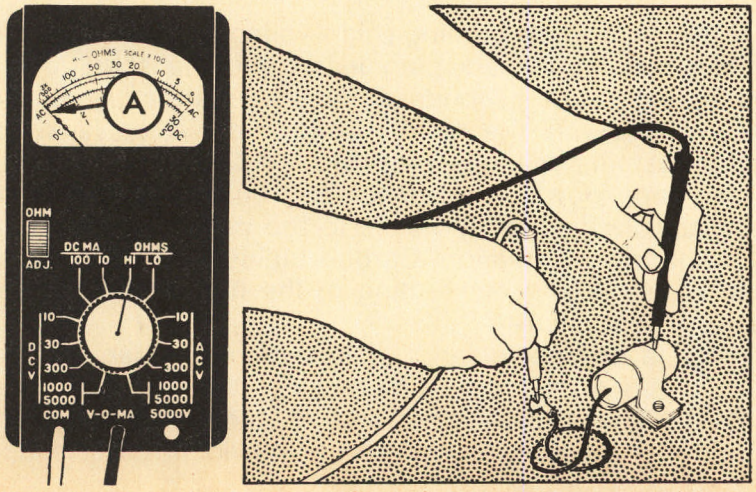
The point setting should be checked with a feeler gauge (A). See the shop manual for proper settings.

If points show only minor pitting or burning, they can be cleaned with a point file and re-gapped instead of being replaced. If pitting or burning is excessive, new points and condenser should be installed.

Point alignment should be checked on points which show mild pitting that is not centered on the point contact surface. Bad point alignment shortens point life considerably, and a poor spark will result until the problem is corrected.

NOTE: IF THE POINTS MUST BE ALIGNED BY BENDING, *NEVER* BEND THE MOVABLE ARM (B). ALWAYS BEND THE FIXED CONTACT (C). ALSO INSPECT THE RUBBING BLOCK (D) ON THE POINTS FOR WEAR AND LUBRICATE IF NECESSARY.

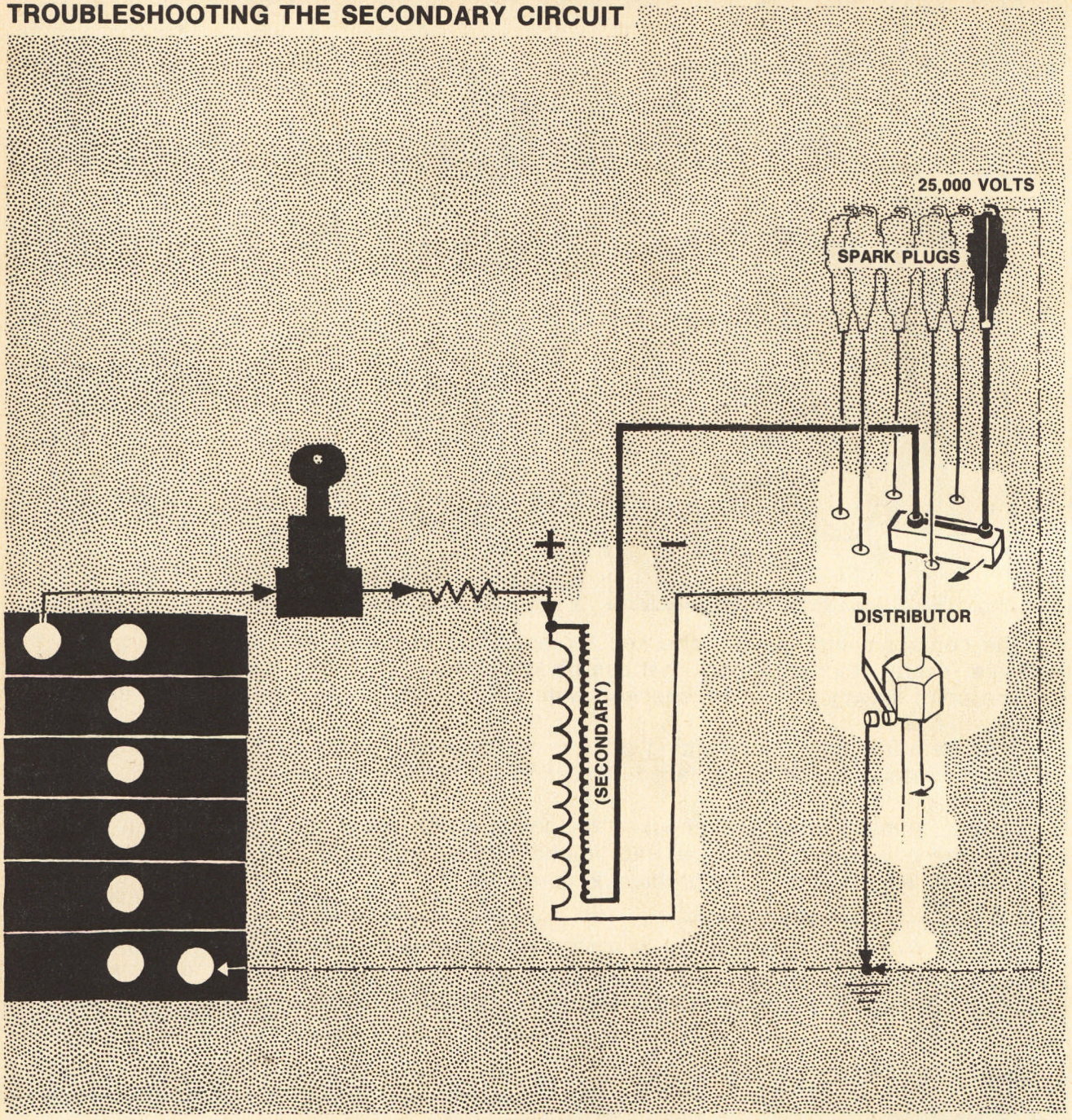
CHECKING THE CONDENSER



The condenser can be checked with the multimeter to determine its electrical condition, but the best course of action when a faulty condenser is suspected is to replace it. If you do wish to check it, remove the condenser from the distributor and connect the multimeter, one lead to one side of the condenser and the other lead to the other side. The meter selector switch should be set to read resistance (ohms) on the highest range. If the reading is below the infinity mark (A—it may drop and then rise to infinity when the meter is first connected), replace the condenser.

TROUBLESHOOTING THE IGNITION SYSTEM

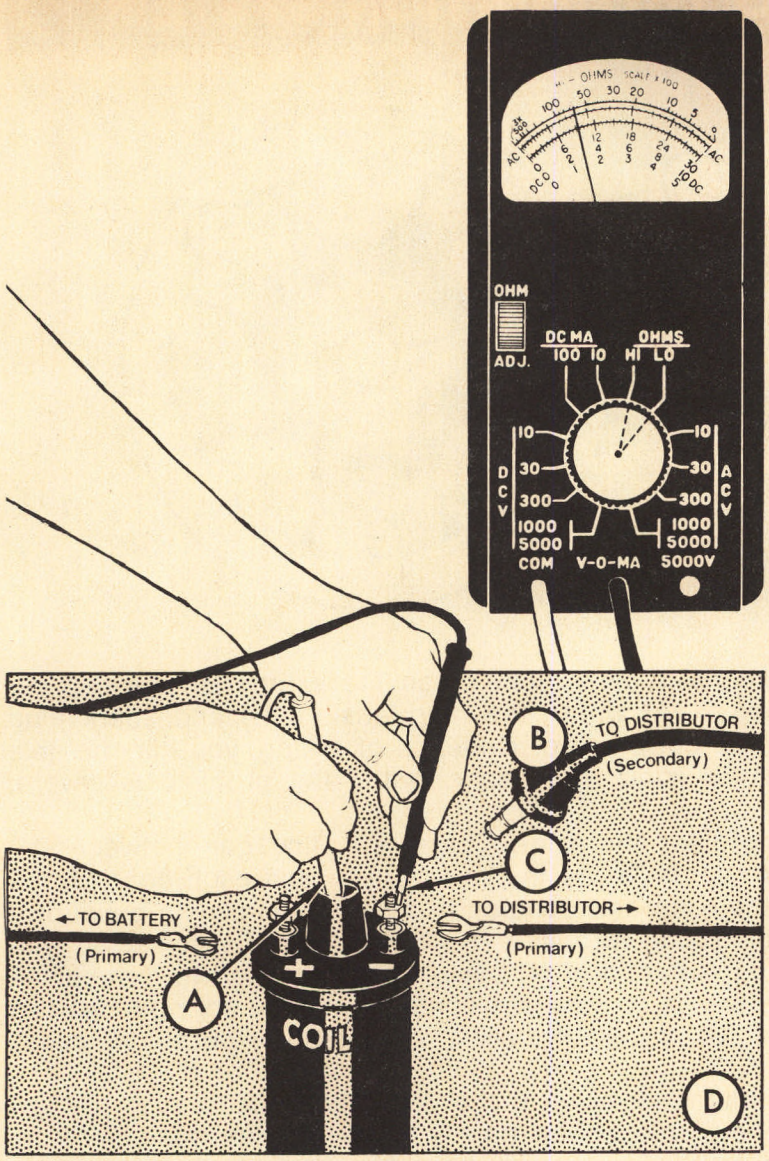
TROUBLESHOOTING THE SECONDARY CIRCUIT



The secondary circuit is made up of the secondary winding (high voltage) of the coil, the distributor cap and rotor, the high-tension lead and spark plug leads and the spark plugs themselves. Careful inspection of all the wiring in the secondary circuit is mandatory. In the primary side of the ignition, the highest voltage was the battery voltage of six or 12 volts, depending on the car. In the secondary system, voltages may exceed 20,000 volts. This extremely high voltage needs only a small breakdown in the insulating qualities of wires or parts to short out. These breakdowns are not always readily visible to the naked eye. Accumulations of oil or grease on wiring can break down insulation. Carbon buildup on spark plugs and the inside of the distributor cap can cause arcing or shorting of the high voltage. Even moisture is a frequent cause of secondary system failure.

All elements of the ignition system should be kept clean and free of oil, dirt and water. Rubberized wiring should be inspected for signs of rotting or cracking. Where spark plug wires pass close to the exhaust manifolds or exhaust pipes, the wires should be inspected for signs of melted or burned insulation. Below is a series of checks on individual parts of the secondary side of the ignition system.

SECONDARY WINDING RESISTANCE CHECK



Set the multimeter selector switch to read resistance and connect it to the coil as shown in drawing (D).

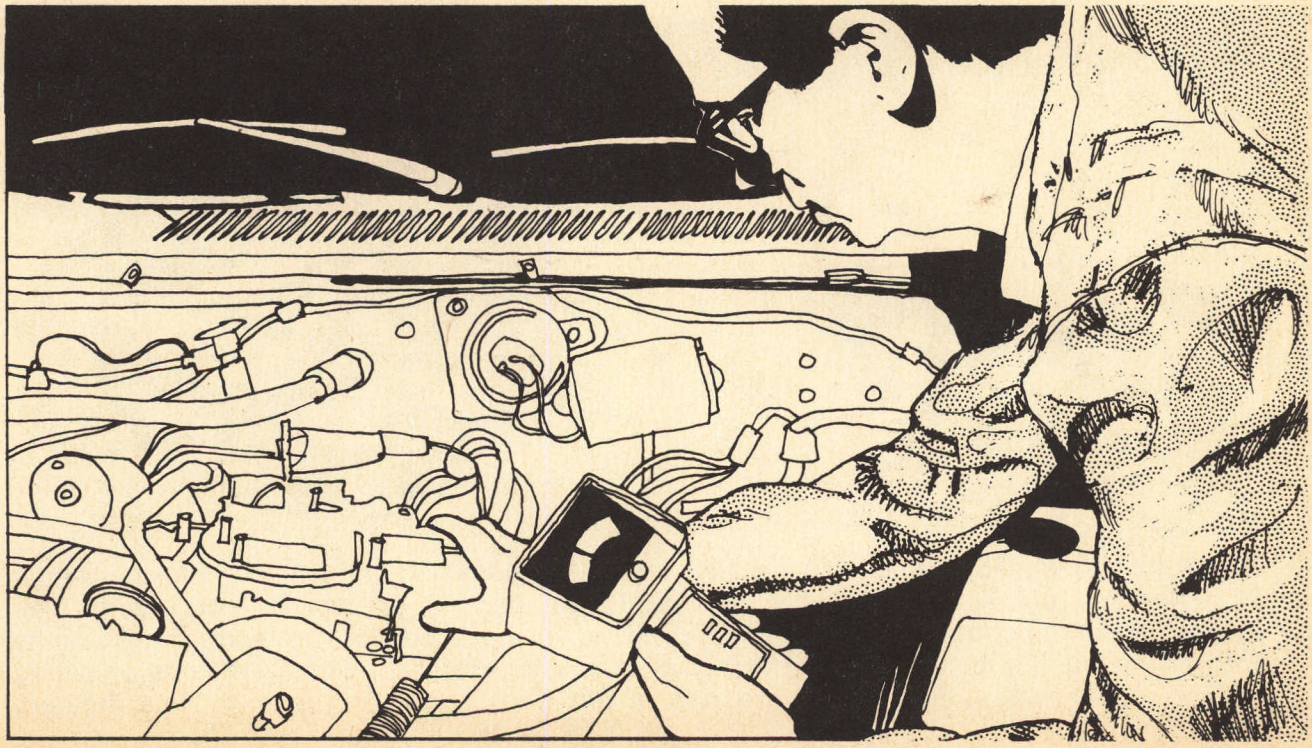
NOTE: SEE PETERSEN'S AUTOMOTIVE TUNE-UP & TEST EQUIPMENT FOR EXACT INFORMATION ON USING THE MULTIMETER.

Remove the high-tension lead (B) and insert one probe (A) into the coil tower. The other probe (C) should be in contact with one of the primary terminals (+) or (-).

The resistance reading should be compared against that listed in the shop manual for the type of automobile you are working on. If the reading is above or below the specification listed, replace the coil.

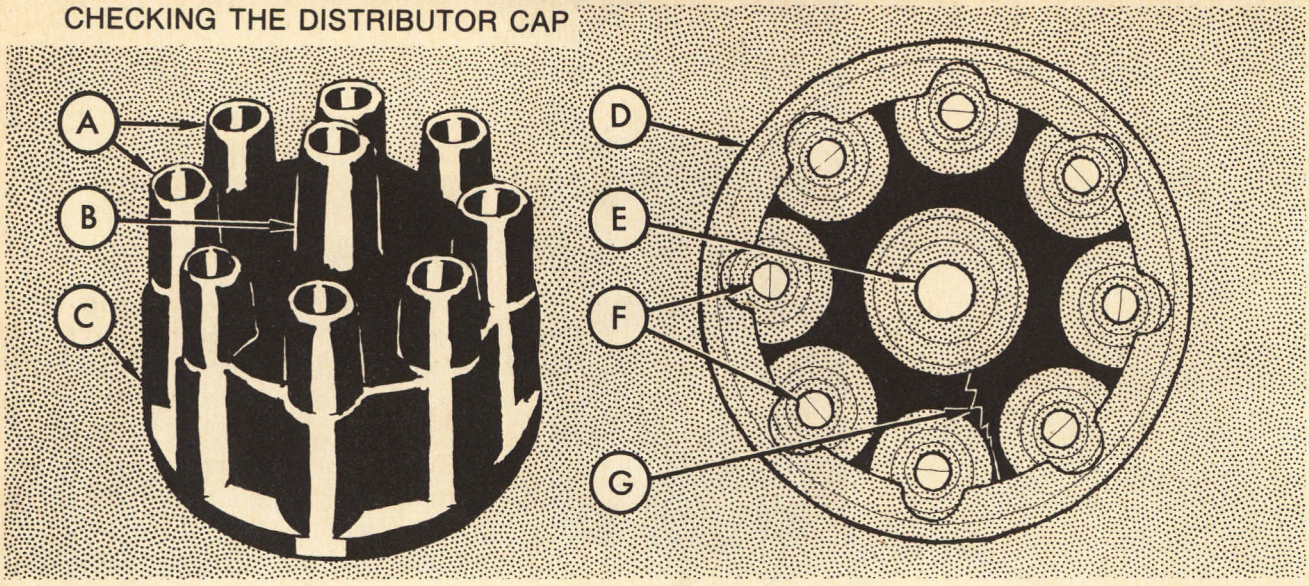
NOTE: THE VALUE OF RESISTANCE VARIES WITH EACH TYPE OF COIL.

This check of the coil with the multimeter is not perfect, as it cannot duplicate the effect of the 20,000 volts. If you desire, a coil can be checked by a shop with specialized test equipment that more closely simulates actual running conditions.



TROUBLESHOOTING THE IGNITION SYSTEM

CHECKING THE DISTRIBUTOR CAP

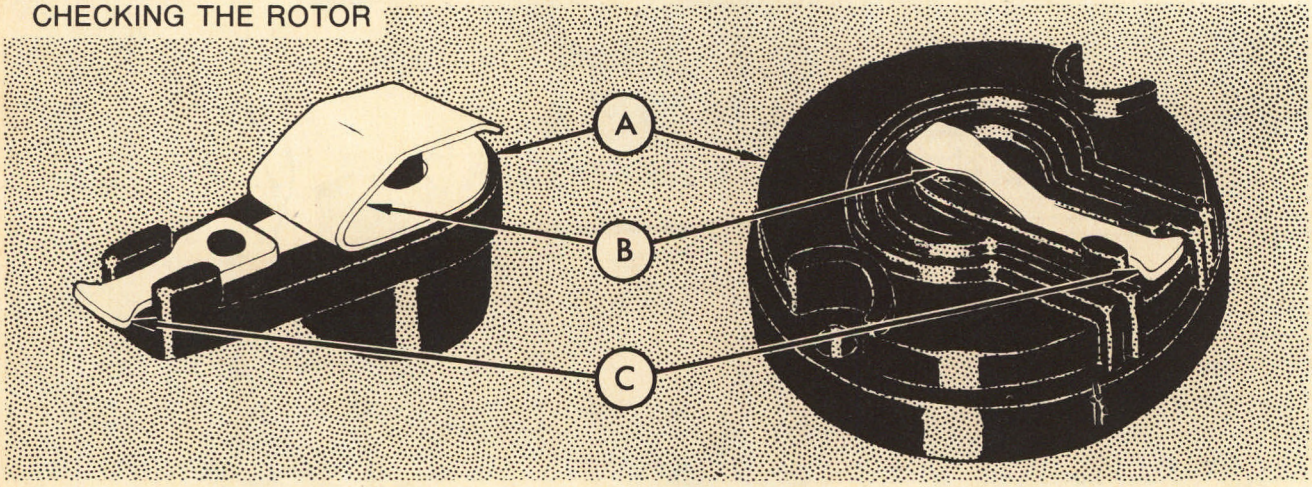


Checking the distributor cap is primarily a visual job. Clean the exterior of the cap (C) carefully and examine all the wire sockets (A) where the high-tension (B) and spark plug wires plug into the cap. If there is any dirt, corrosion or evidence of arcing, you may be able to clean it up with a small wire brush or some sandpaper, but if the problem is severe, replace the cap.

Inside the cap (D) are the contacts (F) for the rotor. There is a tiny gap between the metal tip of the rotor and the spark plug contacts. As the rotor whirls past each contact, the electrical pulse makes an arc between the rotor and contact. In time, this causes a buildup of burned metal particles on the contact or on the rotor tip. The buildup can be corrected with a small file or sandpaper unless the burning is bad. If it appears to be too bad to fix, replace the cap. The center contact (E) on the cap is in constant contact with the spring-tensioned contact on top of the rotor. The former will usually not show any pitting or burning but may be dirty or oily.

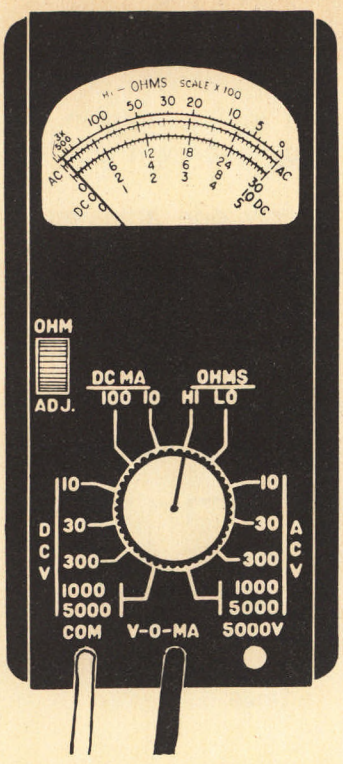
Carefully check inside and out for hairline cracks in the cap. These can cause a short circuit of the high-voltage pulse. On the inside of the cap, a crack (G) can sometimes be detected by a carbon buildup along the crack. This carbon track is a perfect short circuit for the high voltage and can cause failure of the ignition system.

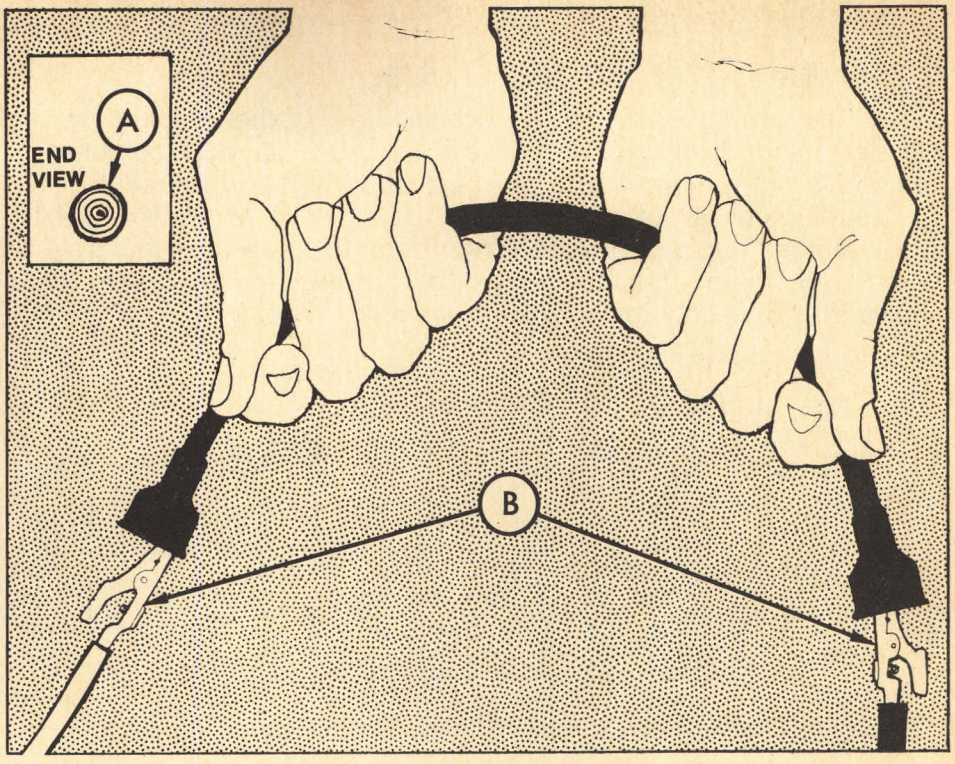
CHECKING THE ROTOR



The rotor (A) can be checked by visual methods. Inspect it for carbon tracking which would indicate a crack and examine the metal contacts (C) for burning or pitting. The spring-loaded center contact (B) should be checked to make sure it has enough tension to keep it in firm touch with the center contact in the distributor cap. Small amounts of pitting can be corrected with a fine file. If the cap is too badly worn to repair by this method, replace it.

CHECKING SECONDARY WIRING





The high-tension and spark plug wires can be checked with the multimeter to make sure they provide a good path for electricity. There are two basic types of wiring used for spark plugs and high-tension leads. The first, which is not found on most modern automobiles as *factory* equipment, is metallic wire. This type has a solid or stranded copper wire center (A) conductor. The second kind of wiring is the resistance wiring used to eliminate electrical interference with radios and other electrical equipment. This second type, which is standard equipment on all modern automobiles, does not use a metallic center conductor. The conductor is a group of nylon or fiberglass fibers which are impregnated with carbon, an excellent conductor of electricity.

All secondary wiring should be free of dirt, oil and grime. The insulated covering should show no signs of burning or cracking. When checking the outside condition of wiring before it is removed from the engine, look closely at those areas where the wire is held in clamps or holders and where it passes close to hot exhaust manifolds or pipes.

The internal condition of the wiring can be checked with the multimeter. Set the multimeter to read resistance (ohms). Use a pair of alligator clips (B) on the test probes, which will leave your hands free to make movement tests.

NOTE: ALLIGATOR CLIPS ARE SMALL, SPRING-LOADED CLAMPS WHICH FASTEN TO THE PROBE TIPS.

Connect the meter probes to each end of the wire (spark plug or high-tension lead). On metallic wire, you should get a very low resistance reading, but on carbon resistance wiring, the reading may be as high as 40 K-ohms (40,000 ohms). If the steady reading is above 40 K-ohms, replace the wire.

In both cases, hold the wire in your hands. Wiggle it and watch the meter. Any fluctuation of the needle, especially if it goes to the high end of the scale (infinity), means that there is a broken or burned spot somewhere inside the wire. Replace such a wire.

CAUTION: WHEN REMOVING WIRES FROM THE DISTRIBUTOR CAP FOR TESTING, REMOVE ONLY ONE WIRE AT A TIME TO PREVENT A MIXUP OF THE FIRING ORDER WHEN RECONNECTING. CARBON RESISTANCE WIRE CAN BE BROKEN BY ROUGH HANDLING. WHEN REMOVING IT FROM SPARK PLUGS AND DISTRIBUTOR CAP, HOLD IT BY THE EXTREME END RATHER THAN PULLING ON THE WIRE.

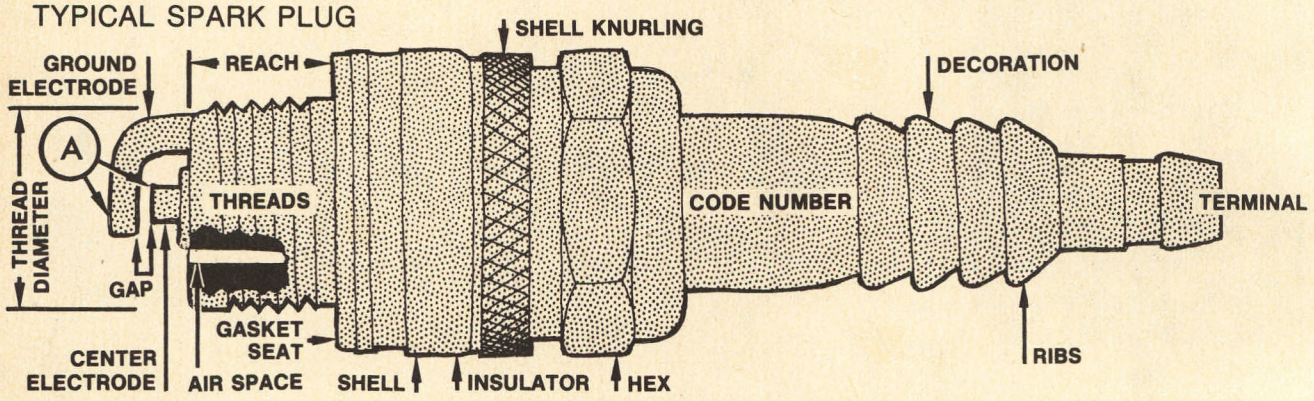
TROUBLESHOOTING THE IGNITION SYSTEM

TROUBLESHOOTING SPARK PLUGS

At the end of the ignition system line is the spark plug, screwed into a hole in the cylinder head. If this part malfunctions, the air/fuel mixture in the cylinder will not fire regardless of the condition of the rest of the ignition system.

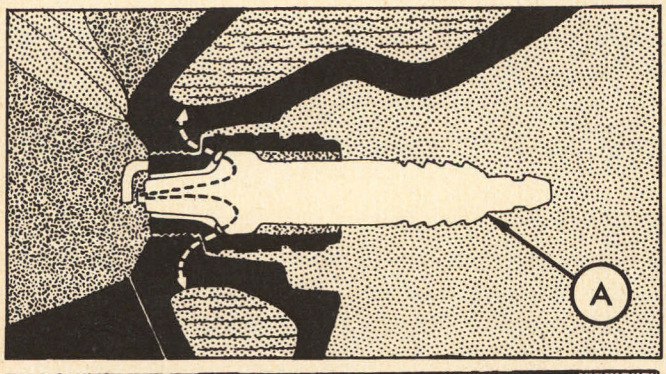
Spark plugs are simple devices. They have no moving parts and only one adjustment. The simplest method of checking them for possible faults is to replace them. However, learning to "read" a spark plug can give the troubleshooter valuable information about the condition of not only the ignition system but other parts of the engine as well.

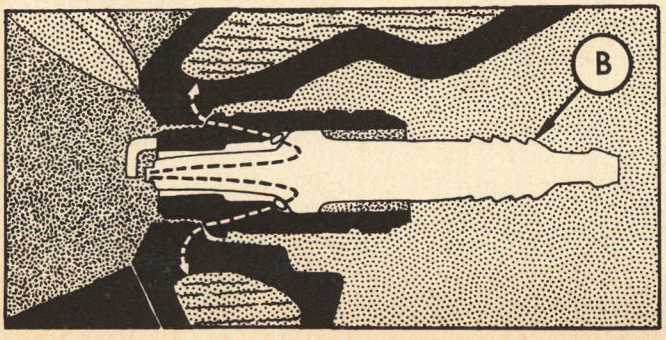
TYPICAL SPARK PLUG



The spark plug does not create the spark. It simply gives the electrical pulse of the ignition secondary a place to make the spark. The two electrodes (A) at the bottom of the spark plug are inside the combustion chamber at the top of the cylinder. When the ignition points open, the high-voltage pulse of electricity flows through the high-tension lead to the distributor, then to the rotor, which sends the pulse to one of the contacts in the cap, then out of the cap and down the spark plug wire to the spark plug. When this high-voltage pulse reaches the center electrode of the spark plug, the tremendous difference between the center electrode and the side electrode, which is grounded, causes a sharp electric arc to jump from one electrode to the other. This arc is what fires the air/fuel mixture.

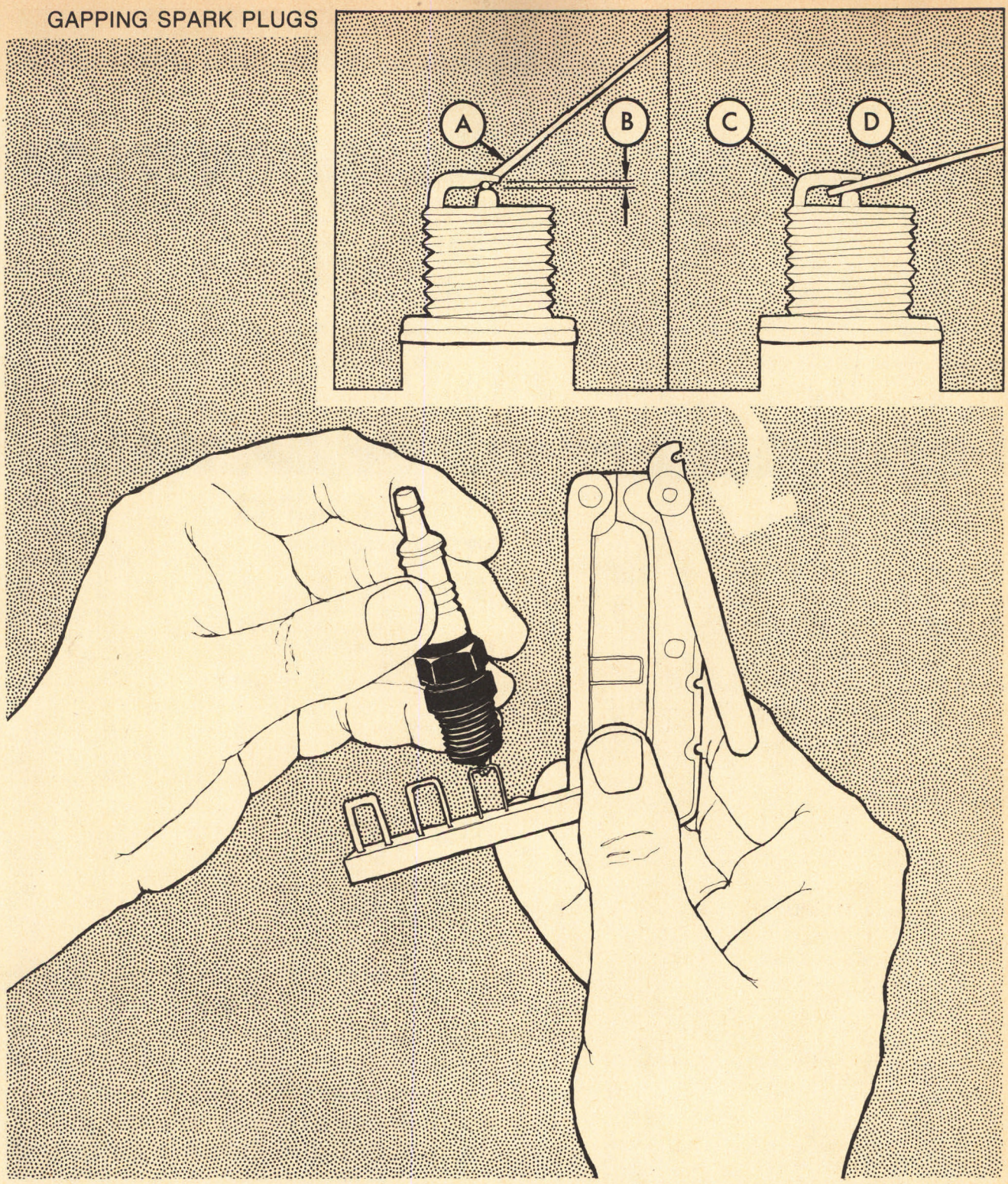
Each spark plug is designed to perform under certain conditions. When replacing spark plugs, always use the recommended plug, unless a competent mechanic advises a change in type for a specific reason. There are conversion charts for spark plugs which convert spark plug numbers of one manufacturer into the system used by another. As long as you follow the directions on these charts, you can use any listed plug.





To suit different engines and varying kinds of driving, spark plugs are designed in different heat ranges. This heat range has nothing to do with the heat of the spark. The heat range refers to the plug's ability to transfer heat from the hot firing tip to where the metal body of the plug touches the cylinder head. The rate of heat transfer is controlled by the distance that heat has to travel. A spark plug with a short heat travel distance (A) is called a "cold" plug. A spark plug with an extra-long heat travel distance (B) is called a "hot" plug. Those with in-between heat conduction properties are known as normal-range plugs. Cold plugs are best used for high-speed operation. Racing cars often use cold plugs. Hot plugs are used for cars that do a lot of short-trip driving with lots of idling. Taxicabs are a good example. The normal plug is the type you are most likely to find in your car. They are used for average driving at both slow and fast speeds.

GAPPING SPARK PLUGS



There is only one adjustment possible on a spark plug. This is an adjustment of the distance between the two electrodes (B). This distance, called "gap," is important to the way the spark produced will fire the air/fuel mixture inside the chamber. If the gap is too narrow, the engine will idle roughly. If the gap is too wide, the spark may not be able to fire across the distance, and the engine will misfire.

A round wire gauge (A) is much better than a flat gauge (D) for gapping spark plugs. Never bend the round center electrode. You will break the insulation around the tip. Always bend the side (or ground) electrode (C). When bending the side electrode to gap the plug, don't pound on it with pliers or a screwdriver handle. Bend the electrode so that the gauge used just slides between the two electrodes with a slight feeling of resistance. A normal gap for most spark plugs used in today's engines is .025-inch to .035-inch. Even though plugs are pre-gapped to the correct range by the factory, you should always check and gap new plugs before installing them.

TROUBLESHOOTING THE IGNITION SYSTEM

SPARK PLUG CHART

AMERICAN MOTORS (Champion)

MAKE, YEAR AND MODEL	STD. PLUG	GAP
ALL MODELS		
6-Cylinder Engines 1971-73 232, 258 cu.in.	N-12Y	.035
1964-70....199, 232 cu. in.	N-14Y	.035
1962-64....196 cu. in. OHV (127-138 hp)	H-14Y	.035
1962-65....196 cu. in. OHV (125 hp)	H-18Y	.035
1962-65....196 cu. in. "L" head	H-10	.035
8-Cylinder Engines 1966-73 290, 304, 343, 360, 390, 401 cu. in.	N-12Y	.035
1970 .....390 cu. in. (340 hp)	N-10Y	.035
1962-66....287, 327 cu. in.	N-14Y	.035
JEEP (American Motors Corp.)		
1972-73....401 cu. in. V-8	N-12Y	.035
1971-73....304, 360 cu. in. V-8	N-12Y	.035
1971-73....232, 258 cu. in. 6-cylinder	N-12Y	.035
1969-71....350 cu. in. V-8	RBL-13Y	.035
1968 .....350 cu. in. V-8	BL-13Y	.035
1966-71....V-6 Engine	J-12Y/UJ-12Y	.035
1965-69....327 cu. in. V-8	H-14Y	.035
1965-70....232 cu. in. 6-cylinder	N-14Y	.035
1963-71....4-cylinder	J-8	.030
1963-66....Tornado Engine	L-12Y/UL-12Y	.030

CHRYSLER CORP. (Champion)

CHRYSLER		
1972-73....440 cu. in. V-8 (4-bbl. carb.)	J-11Y	.035
1972-73....440 cu. in. V-8 (2-bbl. carb.)	J-13Y	.035
1971-72....360 cu. in. V-8	N-13Y	.035
1966-71....440 cu. in. V-8 350 hp	J-13Y	.035
Police & Hi-Perf. Eng. 375 hp	J-11Y	.035
1961-64....361 cu. in. V-8	J-14Y	.035
1959-71....383 cu. in. V-8 (2-bbl. carb.)	J-14Y	.035
1966-67....383 cu. in. (4-bbl. carb.)	J-13Y	.035
Police & Hi-Perf. (4-bbl. carb.)	J-11Y	.035
1968-71....383 cu. in. V-8 (4-bbl. carb.)	J-11Y	.035
1959-65....413 cu. in. V-8:		
Two 4-bbl. carbs. (1963-64)	XJ-11Y	.035
Hi-Perf. 300 Series & Police	J-11Y	.035
Standard Engine	J-14Y	.035
COLT		
(Dodge) 1600cc	N-9Y	.030
CRICKET		
(Plymouth) 1600cc	N-9Y	.025
DODGE		
6-Cylinder Engines 1960-72 (OHV)	N-14Y	.035
1957-59 (L-head)	XJ-7	.035
V-8 Engines		
1972-73....400 cu. in. V-8 (4-bbl. carb.)	J-11Y	.035
(2-bbl. carb.)	J-13Y	.035
1972-73....440 cu. in. V-8	J-11Y	.035
1971-72....318, 360 cu. in.	N-13Y	.035
1973 .....340 cu in.	N-12Y	.035
1968-72....340 cu. in.	N-9Y	.035
1966-71....426 cu. in. (2-4 bbl. carb.)	N-10Y	.035
1966-71....440 cu. in. 350 hp	J-13Y	.035
375, 390 hp.	J-11Y	.035
1965 .....413 cu. in. Standard Eng.	J-14Y	.035
Hi-Performance Eng.	J-11Y	.035
1964-69....273 cu. in. (2-bbl. carb.)	N-14Y	.035
Hi-Performance (4-bbl. carb.)	N-10Y	.035
1973 .....318 cu. in.	N-12Y	.035
1967 .....318 cu. in. 3/8" reach heads	J-14Y	.035
3/4" reach heads	N-14Y	.035
DODGE V-8 Engines (continued)		
1968-70....318 cu. in.	N-14Y	.035
1960-66....318, 361 cu. in.	J-14Y	.035
1960-71....383 cu. in. (2-bbl. carb.)	J-14Y	.035
1960-67....383 cu. in. (4-bbl. carb.)	J-13Y	.035
Police Hi-Performance (4-bbl. carb.)	J-11Y	.035
1968-71....383 cu. in. (4-bbl. carb.)	J-11Y	.035
1963-65....426 cu. in. (Do not use 3/4" reach plugs)	J-11Y	.035
IMPERIAL		
1972 .....440 cu. in.	J-11Y	.035
1970-71....440 cu. in.	RJ-13Y	.035
1966-69....440 cu. in.	J-13Y	.035
1959-65	J-14Y	.035
PLYMOUTH—VALIANT		
6-Cylinder Engines 1960-72 (OHV)	N-14Y	.035
V-8 Engines 1972-73 400 cu.in. (2-bbl. carb.)	J-13Y	.035
1972-73....400 cu. in. (4-bbl. carb.)	J-11Y	.035
1972-73....400 cu. in. V-8 (4-bbl. carb.)	J-11Y	.035
1971-72....318, 360 cu. in.	N-13Y	.035
1968-72....340 cu. in.	N-9Y	.035
1965-69....273 cu. in. Std. Engine:		
2-bbl. carb	N-14Y	.035
Hi-Perf. 4-bbl. carb.	N-10Y	.035
1967 .....318 cu. in. 3/8" reach heads	J-14Y	.035
3/4" reach heads	N-14Y	.035
1968-70....318 cu. in.	N-14Y	.035
1960-66....318, 361 cu. in.	J-14Y	.035
1961-71....383 cu. in. (2-bbl. carb.)	J-14Y	.035
1960-67....383 cu. in. (4-bbl. carb.)	J-13Y	.035
Police Hi-Perf. (4-bbl. carb.)	J-11Y	.035
1968-71....383 cu. in. (4-bbl. carb.)	J-11Y	.035
1966-71....440 cu. in. Police & Hi-Perf.	J-11Y	.035
1966-71....440 cu. in. Standard	J-13Y	.035
1966-71....426 cu. in.	N-10Y	.035
1963-65....426 cu. in.	J-11Y	.035

FORD MOTOR CO. (Autolite)

CAPRI		
1973 .....1.6 liter	AGR32	.030
1973 .....2.0 liter	BRF42	.025
1973 .....2.6 liter	AGR32	.030
1972 .....1.6 liter	AGR22	.030
1972 .....2.0 liter	BRF32	.025
COMET/MONTEGO		
1973 .....460 cu. in. Police	ARF42	.035
1971-73....6 cyl.	BRF82	.035
1971-73....302 C.I.D.	BRF42	.035
1971-73....351 C.I.D.	ARF42	.035
1972-73....400 C.I.D.	ARF42	.035
1972-73....429 C.I.D.	BRF42	.035
1971 .....429 C.I.D. S/T	ARF32	.035
COMET/MONTEGO (continued)		
1971 .....429 C.I.D. A/T	ARF32	.035
1970 .....302 C.I.D.	BF42	.035
1970 .....351 C.I.D.	AF42	.035
1970 .....429 C.I.D. Std. Eng.	BRF42	.035
1970 .....429 C.I.D. CJ	AF32	.035
1969 .....302, 351 2-bbl., 390 C.I.D.	BF42	.035
1969 .....351 4-bbl., 428 C.I.D.	BF32	.035
1968 .....302 C.I.D.	BF42	.035
1968 .....428 C.I.D.	BF32	.035
1967-68....427 C.I.D.	BF32	.035
1963-68....8 cyl. exc. 390 GT	BF42	.035
1966-68....390 C.I.D. GT	BF32	.035
1966-70....6 cyl. w/Thermactor	BF82	.035
1960-67....6 cyl. w/o Thermactor	BF82	.035

MAKE, YEAR AND MODEL	STD. PLUG	GAP
CONTINENTAL		
1973 Mark IV	ARF42	.035
1972 Mark IV	BRF42	.035
1971 Mark III	BRF42	.035
1969-70 Mark III	BF42	.035
COUGAR		
1971-73 351 C.I.D.	ARF42	.035
1971 429 C.I.D. S/T	ARF32	.035
1971 429 C.I.D. A/T	ARF32	.035
1970 302 C.I.D.	AF32	.035
1970 351 C.I.D. 2-bbl.	BF42	.035
4-bbl.	AF42	.035
1970 428 C.I.D. CJ	BF32	.035
1967-69 289, 302, 351 C.I.D. 2-bbl., 390 C.I.D. exc. GT	BF42	.035
1967-69 351 C.I.D. 4-bbl., 390 GT, 427, 428 C.I.D.	BF32	.035
EDSEL		
1960 292 C.I.D.	BF82	.035
1960 352 C.I.D.	BF42	.035
1959-60 6 cyl.	BTF6	.035
1959 292 C.I.D.	BF82	.035
1959 332, 361 C.I.D.	BF42	.035
1958 361, 410 C.I.D.	BF42	.035
FAIRLANE/TORINO		
1973 429 C.I.D.	ARF42	.035
1973 460 C.I.D. Police	ARF42	.035
1971-73 6 cyl.	BRF82	.035
1971-73 302 C.I.D.	BRF42	.035
1971-73 351 C.I.D.	ARF42	.035
1972-73 400 C.I.D.	ARF42	.035
1972-73 429 C.I.D.	BRF42	.035
1971 429 C.I.D. S/T	ARF32	.035
1971 429 C.I.D. A/T	ARF32	.035
1968-70 302 C.I.D.	BF42	.035
1970 351 C.I.D.	AF42	.035
1970 429 C.I.D. Std. Eng.	BRF42	.035
1970 429 C.I.D. CJ	AF32	.035
1966-70 6 cyl. w/Thermactor	BF82	.035
1969 351 C.I.D. 2-bbl.	BF42	.035
1969 351 C.I.D. 4-bbl., 428	BF32	.035
1966-69 390 C.I.D. exc. GT	BF42	.035
1966-69 390 C.I.D. GT	BF32	.035
1966-68 289 C.I.D.	BF42	.035
1967-68 427 C.I.D.	BF32	.035
1965 289 C.I.D. exc. Hi.-Perf.	BF42	.035
Hi-Perf.	BF32	.035
1962-67 6 cyl. w/o Thermactor	BF82	.035
1962-64 8 cyl.	BF42	.035
FALCON		
1963-70 8 cyl.	BF42	.035
1966-70 6 cyl. w/Thermactor	BF82	.035
1960-67 6 cyl. w/o Thermactor	BF82	.035
FORD		
1973 460 C.I.D. Police	ARF42	.035
1971-72 6 cyl.	BRF42	.035
1972 302 C.I.D.	BRF42	.035
1972-73 351, 429 C.I.D. (18mm)	BRF42	.035
1972-73 351, 429 C.I.D. (14mm)	ARF42	.035
1971 302, 351, 390, 429 C.I.D. 2-bbl.	BRF42	.035
1971-72 400 C.I.D.	ARF42	.035
1971 429 C.I.D. 4-bbl.	ARF32	.035
1968-70 302, 351, 390 C.I.D.	BF42	.035
1970 429 C.I.D.	BRF42	.035
1966-70 6-cyl. w/Thermactor, exc. Police & Taxi	BF42	.035
Police & Taxi	BTF6	.035
1968-70 427, 428 C.I.D. Police	BF32	.035
1966-69 289, 352, 390, 428 C.I.D. exc. 428 Police	BF42	.035
1966-67 6 cyl. w/o Thermactor	BF42	.035
1960-65 289, 332, 352, 390 C.I.D. exc. Hi.-Perf.	BF42	.035
352, 390 C.I.D.	BF42	.035
1960-65 406, 427 C.I.D. Hi.-Perf. 352, 390 C.I.D.	BF32	.035
1963 260 C.I.D.	BF42	.035
1960-62 292 C.I.D.	BF82	.035
1959 332, 352 C.I.D.	BF82	.035
1955-65 6 cyl.	BTF6	.035
1955-58 272, 292, 312 C.I.D.	BF82	.035
1954 8 cyl.	AL7	.030
1952-54 6 cyl.	AL7	.030
1949-53 8 cyl.	AL9	.030
1949-51 6 cyl.	AL9	.030
1938-48 All	AL9	.030
LINCOLN		
1973 460 C.I.D.	ARF42	.035
1971-72 460 C.I.D.	BRF42	.035
1968-70 460 C.I.D.	BF42	.035
1966-68 462 C.I.D.	BTF42	.035
1961-65	BF42	.035
1958-60	BF42	.035
1955-57	BF82	.035
1953-54	AL7	.030
1940-52	AL9	.030
MAVERICK		
1971-73 6 cyl.	BRF82	.035
1972 302 C.I.D.	BRF42	.035
1970 6 cyl.	BF82	.035
MERCURY		
1973 460 C.I.D.	ARF42	.035
1973 460 C.I.D. Police	ARF42	.035
1972-73 351, 429 C.I.D. (14mm)	ARF42	.035
1972-73 429, 460 C.I.D. (18mm)	BRF42	.035
1971 351, 429 C.I.D. 2-bbl.	BRF42	.035
1971-73 400 C.I.D.	ARF42	.035
1971 429 C.I.D.	ARF32	.035
1970 390 C.I.D.	BF42	.035
1970 428 C.I.D.	BF32	.035
1970 429 C.I.D.	BRF42	.035
1969 429 C.I.D.	BF42	.035
1968-69 390, 428 C.I.D. exc. Police	BF42	.035
1968-69 428 C.I.D. Police	BF32	.035
1961-67 352, 390, 410, 428 C.I.D. exc. Hi-Perf.	BF42	.035
1961-67 406, 427 C.I.D. Hi.-Perf. 352, 390, 428 C.I.D.	BF32	.035
1961-62 6 cyl.	BTF6	.035
1960-61 292, 312 C.I.D.	BF82	.035
1960-61 383, 430 C.I.D.	BF42	.035
1959 312 C.I.D.	BF82	.035
1958-59 383, 430 C.I.D.	BF42	.035
1957-58 312 C.I.D.	BF82	.035
1957 368 C.I.D.	BF82	.035
1955-56 All	BF82	.035
1949-54 All	AL7	.030
1939-48 All	AL9	.030
MUSTANG		
1971-73 6 cyl.	BRF82	.035
1972-73 302 C.I.D.	BRF42	.035
1971 302 C.I.D. 2-bbl.	BRF42	.035
1971 302 C.I.D. 4-bbl.	ARF32	.035
1971-73 351 C.I.D.	ARF42	.035
1971 429 C.I.D. S/T	ARF32	.035
1971 429 C.I.D. A/T	ARF32	.035
1970 302 C.I.D. exc. H.O. Eng.	BF42	.035
1970 302 C.I.D. H.O. Eng.	AF32	.035
1970 351 C.I.D. 2-bbl.	BF42	.035
1970 351 C.I.D. 4-bbl.	AF42	.035
1970 428 C.I.D.	BF32	.035
1970 429 C.I.D.	AF32	.035
1969 302, 351 C.I.D. 2-bbl.	BF42	.035
1969 351 4-bbl., 428 C.I.D.	BF32	.035
1969 390 C.I.D.	BF42	.035
1968 289, 302, 390 C.I.D. exc. GT	BF42	.035
1968 390 GT, 428 C.I.D.	BF32	.035
1967-70 6 cyl. w/Thermactor	BF82	.035
1965-67 6 cyl. w/o Thermactor	BF82	.035
1965-67 289 C.I.D. exc. Hi.-Perf.	BF42	.035
1965-67 289 C.I.D. Hi.-Perf.	BF32	.035
1967 390 C.I.D.	BF42	.035
1965 260 C.I.D.	BF42	.035
PINTO		
1973 1600cc	AGR32	.030
1972 1600cc	AGR22	.030
1972-73 2000cc	BRF42	.035
1971 1600cc	AGR22	.030
1971 2000cc	BRF32	.025
THUNDERBIRD		
1973 429 C.I.D.	ARF42	.035
1973 460 C.I.D.	ARF42	.035
1970-72 429 C.I.D.	BRF42	.035
1972 460 C.I.D.	BRF42	.035
1960-69	BF42	.035
1958-59 352, 430 C.I.D.	BF42	.035
1955-57	BF82	.035

TROUBLESHOOTING THE IGNITION SYSTEM

GENERAL MOTORS (AC)

MAKE, YEAR AND MODEL	PLUG TYPE ACNITER	PLUG TYPE STANDARD	PLUG GAP
BUICK			
Centurion, Electra, Wildcat (thru 1970), Riviera, Estate Wagon, Riviera GS			
1973-72 V-8	R45TS	—	.040
1971-69 V-8	R44TS	—	.030
1968-67 V-8	R44TS	44TS	.030
1966-59 V-8	R44S	44S	.035
LeSabre, Sportwagon			
1973-72 V-8 350	R45TS	—	.040
1971-69 V-8 350	R45TS	—	.030
1968 V-8 350	R45TS	45TS	.030
1973-72 V-8 455	R45TS	—	.040
1971-70 V-8 455	R44TS	—	.030
Skylark, Century, Luxus, Regal, Luxus Wagon			
1971 6 Cyl. 250 1 Bbl.	R46TS	—	.035
1970 6 Cyl.	R46T	—	.035
1969 6 Cyl.	R46N	—	.035
1968 6 Cyl. 250	R46N	46N	.035
1967-62 V-6	R44S	44S	.035
1967-65 V-8 300, 340, 2 Bbl Carb.	R45S	45S	.035
4 Bbl. Carb.	R44S	44S	.035
1973-72 V-8 350	R45TS	—	.040
1971-69 V-8 350	R45TS	—	.030
1968 V-8 350	R45TS	45TS	.030
1969 V-8 400	R44TS	—	.030
1966-65 V-8 400	R44S	44S	.035
1973-72 V-8 455	R45TS	—	.040
1971-70 V-8 455	R44TS	—	.030
CADILLAC			
Calais, DeVille, Fleetwood, Eldorado			
1973-70 V-8	R46N	—	.035
1969 V-8	R44N	—	.035
1968 V-8	R44N	44N	.035
CHEVROLET			
Bel Air, Biscayne, Impala, Caprice, Brookwood, Townsman, Kingsman			
1973-72 6 Cyl. 250	R46T	—	.035
1971 6 Cyl. 250 1 Bbl.	R46TS	—	.035
1970 6 Cyl. 250	R46T	—	.035
1969 6 Cyl.	R46N	—	.035
1968-62 6 Cyl. 230, 250, 194	R46N	46N	.035
1962-53 6 Cyl. 235	R45	45	.035
1957-55 V-8 265	R45	45	.035
1967-57 V-8 283	R45	45	.035
1968 V-8 307	R45S	45S	.035
1969 V-8 327	R45	—	.035
1968-62 V-8 327	R45S	45S	.035
1961-59 V-8 348	R44N	44N	.035
1973-72 V-8 350 2 Bbl or 4 Bbl	R44T	—	.035
1971 V-8 350 2 Bbl. (245 h.p.)	R45TS	—	.035
4 Bbl. (270 h.p.)	R44TS	—	.035
1970-69 V-8 350	R44	—	.035
1968-67 V-8 350	R44	44	.035
1969 V-8 396 (265 h.p.)	R44N	—	.035
1968-65 V-8 396 Normal Service	R44N	44N	.035
Light Service	R46N	46N	.035
1973-72 V-8 400 2 Bbl.	R44T	—	.035
1971 V-8 400 2 Bbl. (255 h.p.)	R44TS	—	.035
1970 V-8 400 (265 h.p.)	R44	—	.035
1972 V-8 402 4 Bbl.	R44T	—	.035
1971 V-8 402 4 Bbl. (300 h.p.)	R44TS	—	.035
1969 V-8 427 (335 h.p.)	R44N	—	.035
Bel Air, Biscayne, Impala, Caprice, Brookwood, Townsman, Kingsman			
1969 V-8 427 (390, 425 h.p.)	R43N	—	.035
1968-66 V-8 427 Cast Iron Head	R43N	43N	.035
1968-67 V-8 427 Aluminum Head	R43XL	43XL	.035
1973-72 V-8 454 4 Bbl.	R44T	—	.035
1971 V-8 454 4 Bbl. (365 h.p.)	R43TS	—	.035
1970 V-8 454 (345 h.p.)	R44T	—	.035
1970 V-8 454 (390 h.p.)	R43T	—	.035
Camaro-SS-Rally Sport			
1973-72 6 Cyl. 250	R46T	—	.035
1971 6 Cyl. 250 1 Bbl.	R46TS	—	.035
1970 6 Cyl.	R46T	—	.035
1969 6 Cyl.	R46N	—	.035
1968-67 6 Cyl.	R46N	46N	.035
1969 V-8 302	R43	—	.035
1968-67 V-8 302	CR43	C43	.035
1973-72 V-8 307 2 Bbl.	R44T	—	.035
1971 V-8 307 2 Bbl.	R45TS	—	.035

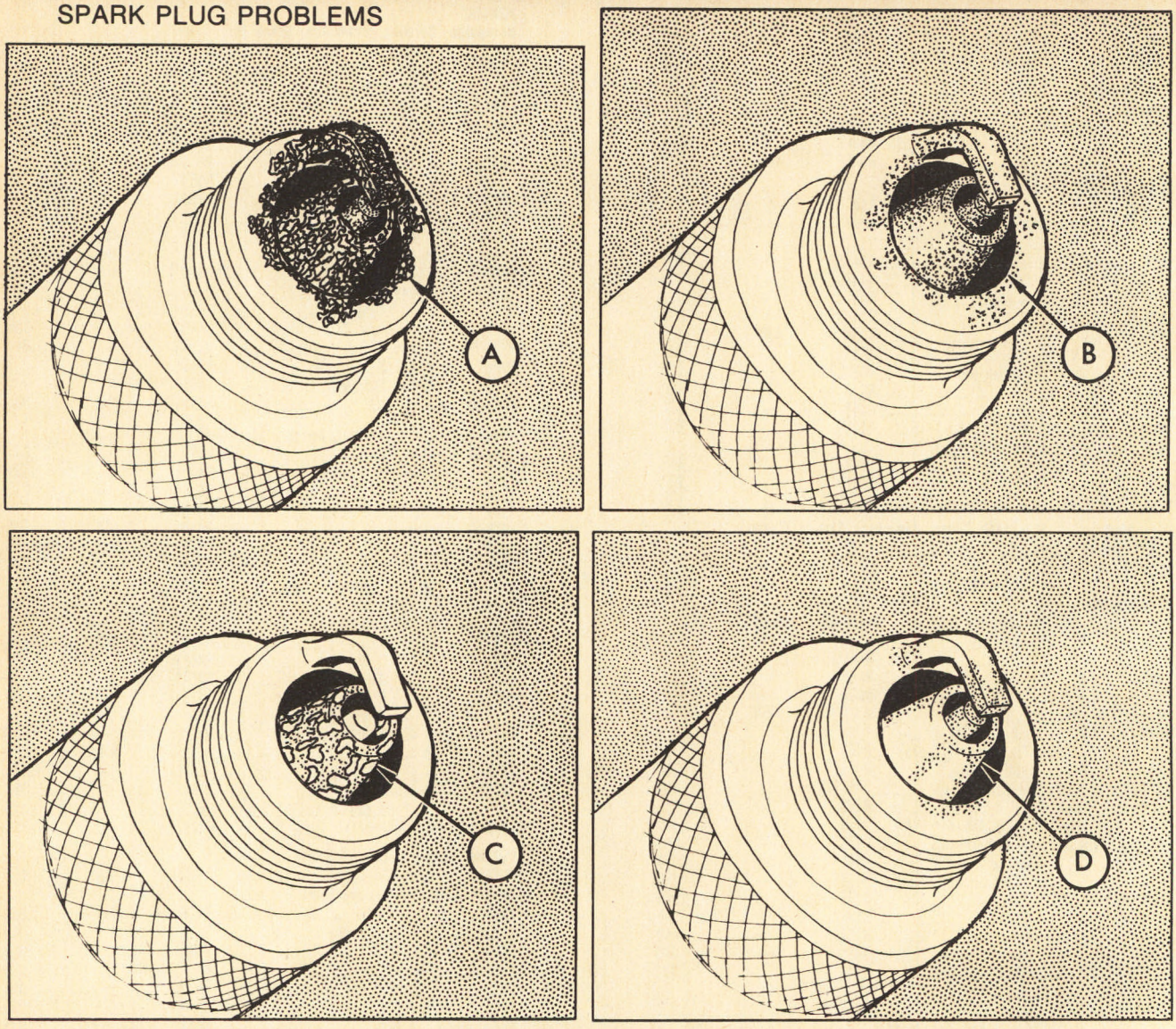
MAKE, YEAR AND MODEL	PLUG TYPE ACNITER	PLUG TYPE STANDARD	PLUG GAP
CHEVROLET Cont.			
1970-69 V-8 307	R45	—	.035
1969 V-8 327	R45	—	.035
1968-67 V-8 327	R45S	45S	.035
1973-72 V-8 350 2 Bbl.	R44T	—	.035
4 Bbl.	R44T	—	.035
4 Bbl. (Z28)	R44T	—	.035
1971 V-8 350 2 Bbl. (245 h.p.)	R45TS	—	.035
4 Bbl. (270 h.p.)	R44TS	—	.035
4 Bbl. (330 h.p.) Z28	R44TS	—	.035
1970-69 V-8 350 (250, 300 h.p.)	R44	—	.035
1970 V-8 350 (360 h.p.)	R43	—	.035
1968-67 V-8 350	R44	44	.035
1969 V-8 396 Cast Iron Head (325 h.p.)	R44N	—	.035
(350, 375 h.p.)	R43N	—	.035
1969 V-8 396 Aluminum Head	R43XL	—	.035
1968-67 V-8 396 Normal Service	R44N	44N	.035
Light Service	R46N	46N	.035
1972 V-8 402 4 Bbl.	R44T	—	.035
1971 V-8 402 4 Bbl. (300 h.p.)	R44TS	—	.035
1970 V-8 402 (396 SS)(350 h.p.)	R44T	—	.035
(375 h.p.)	R43T	—	.035
1970 V-8 454	R43T	—	.035
Chevelle, Laguna, Monte Carlo			
1973-72 6 Cyl. 250 1 Bbl.	R46T	—	.035
1971 6 Cyl. 250 1 Bbl.	R46TS	—	.035
1970 6 Cyl.	R46T	—	.035
1969 6 Cyl.	R46N	—	.035
1968-64 6 Cyl.	R46N	46N	.035
1967-64 V-8 283	R45	45	.035
1973-72 V-8 307 2 Bbl.	R44T	—	.035
1971 V-8 307 2 Bbl.	R45TS	—	.035
1970-69 V-8 307	R45	—	.035
1968 V-8 307	R45S	45S	.035
1969 V-8 327	R45	—	.035
1968-65 V-8 327	R45S	45S	.035
1973-72 V-8 350 2 Bbl.	R44T	—	.035
4 Bbl.	R44T	—	.035
1971 V-8 350, 2 Bbl. (245 h.p.)	R45TS	—	.035
4 Bbl. (270 h.p.)	R44TS	—	.035
1970-69 V-8 350 (250, 300 h.p.)	R44	—	.035
1968-67 V-8 350	R44	44	.035
1969 V-8 396 Cast Iron Head (325 h.p.)	R44N	—	.035
(350, 375 h.p.)	R43N	—	.035
1969 V-8 396 Aluminum Head	R43XL	—	.035
1968-65 V-8 396 Normal Service	R44N	44N	.035
Light Service	R46N	46N	.035
1971 V-8 400 2 Bbl. (255 h.p.)	R44TS	—	.035
1970 V-8 400 (265 h.p.)	R44	—	.035
1972 V-8 402 4 Bbl.	R44T	—	.035
1971 V-8 402 4 Bbl. (300 h.p.)	R44TS	—	.035
1970 V-8 402 (330 h.p.)	R44T	—	.035
1970 V-8 402 (396 SS) (350 h.p.)	R44T	—	.035
1970 V-8 402 (396 SS) (375 h.p.)	R43T	—	.035
1973-72 V-8 454 4 Bbl.	R44T	—	.035
1971 V-8 454 4 Bbl. (365 h.p.)	R43TS	—	.035
4 Bbl. (425 h.p.)	R44TS	—	.035
Chevelle & Monte Carlo			
1970 V-8 454 (360, 450 h.p.)	R43T	—	.035
1970 V-8 454 (460 h.p.) w/Alum. Hd.	R43XL	—	.035
Chevy Nova (Chevy II)			
1970-69 4 Cyl.	R46N	—	.035
1968-62 4 & 6 Cyl.	R46N	46N	.035
1973-72 6 Cyl. 250 1 Bbl.	R46T	—	.035
1971 6 Cyl. 250 1 Bbl.	R46TS	—	.035
1970 6 Cyl.	R46T	—	.035
1969 6 Cyl.	R46N	—	.035
1967-64 V-8 283	R45	45	.035
1973-72 V-8 307 2 Bbl.	R44T	—	.035
1971 V-8 307 2 Bbl.	R45TS	—	.035
1970-69 V-8 307	R45	—	.035
1968 V-8 307	R45S	45S	.035
1969 V-8 327	R45	—	.035
1968-65 V-8 327	R45S	45S	.035
1973-72 V-8 350 2 Bbl.	R44T	—	.035
4 Bbl.	R44T	—	.035
1971 V-8 350 2 Bbl. (245 h.p.)	R45TS	—	.035
4 Bbl. (270 h.p.)	R44TS	—	.035
1970-69 V-8 350	R44	—	.035
1968 V-8 350	R44	44	.035

MAKE, YEAR AND MODEL	PLUG TYPE ACNITER	PLUG TYPE STANDARD	PLUG GAP
CHEVROLET (Cont.)			
1969..... V-8 396 (350, 375 h.p.)	R43N	—	.035
1970..... V-8 402 (396 SS)(350 h.p.)	R44T	—	.035
(375 h.p.)	R43T	—	.035
Corvair			
1969..... 6 Cyl. 164	R44FF	—	.030
1968-60.... Std. Eng	R46FF	46FF	.035
High Perf	R44FF	44FF	.030
Corvette			
1968-62.... V-8 327	R44	44	.035
1973-72.... V-8 350 4 Bbl.(260 h.p.)	R44T	—	.035
(LT1 or Z28)	R44T	—	.035
1971..... V-8 350 4 Bbl. (270 h.p.)	R44TS	—	.035
4 Bbl. (330 h.p. LT1)	R44TS	—	.035
1970..... V-8 350 (370 h.p.)	R43	—	.035
1970-69.... V-8 350 (300, 350 h.p.)	R44	—	.035
1965..... V-8 396	R43N	43N	.035
1969..... V-8 427 Cast Iron Head	R43N	—	.035
Aluminum Head	R43XL	—	.035
1968-66.... V-8 427	R43N	43N	.035
1973-72.... V-8 454 4 Bbl	R44T	—	.035
1971..... V-8 454 4 Bbl. (365 h.p.)	R43TS	—	.035
1971..... V-8 454 4 Bbl. (425 h.p.) Alum. Head	R44XL	—	.035
1970..... V-8 454 (390 h.p.)	R43T	—	.035
1970..... V-8 454 (460 h.p.) w/Alum. Hd	R43XL	—	.035
Vega 2300 Sedan, Hatchback Coupe, Kammback Station Wagon, Panel Express Wagon			
1973-71.... 4 Cyl. 140 1 Bbl. 90 h.p.	R42TS	—	.035
2 Bbl. 110 h.p.	R42TS	—	.035
OLDSMOBILE			
F-85, Cutlass Supreme, Cutlass S Cruiser, Vista-Cruiser, Omega			
1973..... 6 Cyl. 250 (Omega)	R46T	—	.035
1971..... 6 Cyl. 250 1 Bbl	R46TS	—	.035
1970..... 6 Cyl. 250	R46T	—	.035
1969..... 6 Cyl. 250	R46N	—	.035
1968-66.... 6 Cyl. 250	R46N	46N	.035
1973-71.... V-8 350 All 2 & 4 Bbl. w/Auto Trans. (Incl. Omega)	R46S	—	.040
4 Bbl. w/Man Trans	R45S	—	.040
1970-69.... V-8 350 Low Comp. 2 Bbl	R46S	—	.030
High Comp. 4 Bbl	R45S	—	.030
High Comp. 4 Bbl. Force Air	R43S	—	.030
1969..... V-8 400 Low Compression	R45S	—	.030
High Compression	R44S	—	.030
Police Option	R43S	—	.030
1973-71.... V-8 455 2 Bbl	R46S	—	.040
4 Bbl. (Exc.4-4-2)	R46S	—	.040
4 Bbl. (4-4-2)	R45S	—	.040
4 Bbl. w30 option (4-4-2)	R45S	—	.040
1970..... V-8 455 High Comp. 2 Bbl	R45S	—	.030
High Comp. 4 Bbl. Vista Cruiser	R45S	—	.030
High Comp. 4 Bbl. Exc. Vista Cruiser	R44S	—	.030
1968..... V-8 350 Low Compression	R46S	46S	.030
High Compression	R45S	45S	.030
1968..... V-8 400 Low Compression	R45S	45S	.030
High Compression	R44S	44S	.030
Police Option	R43S	43S	.030
1967-65.... V-8 400 High Compression	R44S	44S	.030
1967-64.... V-8 330 Low Compression	R45S	45S	.030
High Compression	R44S	44S	.030
Delta 88, 98, Custom Royale, Cruiser, Toronado			
1967-64.... V-8 330 Low Compression	R45S	45S	.030
High Compression	R44S	44S	.030
1973-71.... V-8 350 2 & 4 Bbl. Auto Trans	R46S	—	.040
V-8 350 4 Bbl. Man. Trans	R45S	—	.040
1970-69.... V-8 350 Low Compression 2 Bbl	R46S	—	.030
1969..... V-8 350 High Compression	R45S	—	.030
1968..... V-8 350 Low Compression	R46S	46S	.030
High Compression	R45S	45S	.030
1967-65.... V-8 425 Low Compression	R45S	45S	.030
High Compression	R44S	44S	.030
Police Option	R43S	43S	.030
1973-71.... V-8 455 2 Bbl. & 4 Bbl. w/Auto Trans	R46S	—	.040
4 Bbl. w/Man. Trans	R45S	—	.040
1970-69.... V-8 455 Low Compression 2 Bbl	R46S	—	.030
High Compression 4 Bbl	R45S	—	.030
Police Options & Toronado Perf. Pkg	R44S	—	.030
1968..... V-8 455 Low Compression	R45S	45S	.030
High Compression	R44S	44S	.030
Police Option	R43S	43S	.030

MAKE, YEAR AND MODEL	PLUG TYPE ACNITER	PLUG TYPE STANDARD	PLUG GAP
PONTIAC			
Bonneville, Catalina, Grandville, Grand Prix			
1973-72.... V-8 350 2 Bbl	R46TS	—	.040
1971..... V-8 350 2 Bbl	R47S	—	.035
1970..... V-8 350 2 Bbl	R46S	—	.035
1966-63.... V-8 389	R45S	45S	.035
1973-72.... V-8 400 2 Bbl	R46TS	—	.040
4 Bbl	R45TS	—	.040
1971..... V-8 400 2 Bbl. (265 h.p.)	R47S	—	.035
4 Bbl. (300 h.p.)	R46S	—	.035
1970-69.... V-8 400 Grand Prix	R45S	—	.035
1970-69.... V-8 400 Exc. Grand Prix	R46S	—	.035
1968-67.... V-8 400	R45S	45S	.035
1966-63.... V-8 421	R44S	44S	.035
1968-67.... V-8 428	R44S	44S	.035
1969..... V-8 428 Manual Trans	R44S	—	.035
Auto. Trans	R45S	—	.035
Auto Trans. (H.O.)	R44S	—	.035
1973-72.... V-8 455 2 Bbl. or 4 Bbl	R45TS	—	.040
1971..... V-8 455 2 Bbl. & 4 Bbl	R46S	—	.035
1970..... V-8 455 Std. & H. O	R46S	—	.035
1962-60.... V-8	R45S	45S	.035
Firebird, Trans. Am. Esprit, Formula 350-400-455			
1973-72.... 6 Cyl. 250 1 Bbl	R46T	—	.035
1971..... 6 Cyl. 250 1 Bbl	R46TS	—	.035
1970..... 6 Cyl	R46T	—	.035
1969..... 6 Cyl	R44NS	—	.035
1968-67.... 6 Cyl	R44NS	44N	.035
1967..... V-8 326	R45S	45S	.035
1973-72.... V-8 350 2 Bbl	R46TS	—	.040
1971..... V-8 350 2 Bbl	R47S	—	.035
1970-69.... V-8 350 2 Bbl	R46S	—	.035
1969..... V-8 350 4 Bbl	R45S	—	.035
1968-67.... V-8 350	R45S	45S	.035
1973-72.... V-8 400 2 Bbl	R46TS	—	.040
4 Bbl	R45TS	—	.040
1971..... V-8 400 2 Bbl. (265 h.p.)	R47S	—	.035
4 Bbl. (300 h.p.)	R46S	—	.035
1970-69.... V-8 400 4 Bbl	R45S	—	.035
1968-67.... V-8 400	R44S	44S	.035
1973-72.... V-8 455, LS 5, H.O	R45TS	—	.040
1971..... V-8 455 4 Bbl	R46S	—	.035
4 Bbl. (H.O. 335 h.p.)	R46S	—	.035
1970..... V-8 400 Ram Air III & IV	R44S	—	.035
Lemans (Tempest), Lemans Sport			
1968-67.... 6 Cyl. 230	R44NS	44NS	.035
Lemans (Tempest), Lemans Sport			
1966..... 6 Cyl. 230	R44S	44S	.035
1973-72.... 6 Cyl. 250 1 Bbl	R46T	—	.040
1971..... 6 Cyl. 250 1 Bbl	R46TS	—	.035
1970..... 6 Cyl	R46T	—	.035
1969..... 6 Cyl. 250 OHC	R44NS	—	.035
1970-69.... V-8 2 Bbl	R46S	—	.035
1970-69.... V-8 4 Bbl	R45S	—	.035
1968-63.... V-8	R45S	45S	.035
1973-72.... V-8 350 2 Bbl	R46TS	—	.040
1971..... V-8 350 2 Bbl	R47S	—	.035
1973-72.... V-8 400 2 Bbl	R46TS	—	.040
4 Bbl	R45TS	—	.040
1971..... V-8 400 2 Bbl. (265 h.p.)	R47S	—	.035
4 Bbl. (300 h.p.)	R46S	—	.035
1973-72.... V-8 455 4 Bbl. & H.O	R45TS	—	.040
4 Bbl., S.D	R44TS	—	.040
1971..... V-8 455 4 Bbl. (325 h.p.)	R46S	—	.035
4 Bbl GT (335 h.p. (HO)	R46S	—	.035
GTO, The Judge, GT-37			
1973-72.... V-8 400 4 Bbl	R46TS	—	.040
1971..... V-8 400 4 Bbl. (300 h.p.)	R46S	—	.035
1969..... V-8 400 2 Bbl	R46S	—	.035
1970-69.... V-8 400 4 Bbl	R45S	—	.035
1970-69.... V-8 400 Ram Air III, IV	R44S	—	.035
1968-67.... V-8 400 2 Bbl. Carb	R45S	45S	.035
1968-67.... V-8 400 4 Bbl. Carb	R44S	44S	.035
1966-64.... V-8	R44S	44S	.035
1973-72.... V-8 455 4 Bbl. & H.O	R45TS	—	.040
4 Bbl. S.D	R44TS	—	.040
1971..... V-8 455 4 Bbl	R46S	—	.035
4 Bbl. (335 h.p. H.O.)	R46S	—	.035
1970..... V-8 455 4 Bbl	R46S	—	.035
Ventura II			
1971..... 6 Cyl	R46TS	—	.035
1973-72.... 6 Cyl	R46T	—	.035
1971..... V-8 307	R45TS	—	.035
1973-72.... V-8 307	R44T	—	.035
1973-72.... V-8 350	R46TS	—	.040

TROUBLESHOOTING THE IGNITION SYSTEM

SPARK PLUG PROBLEMS



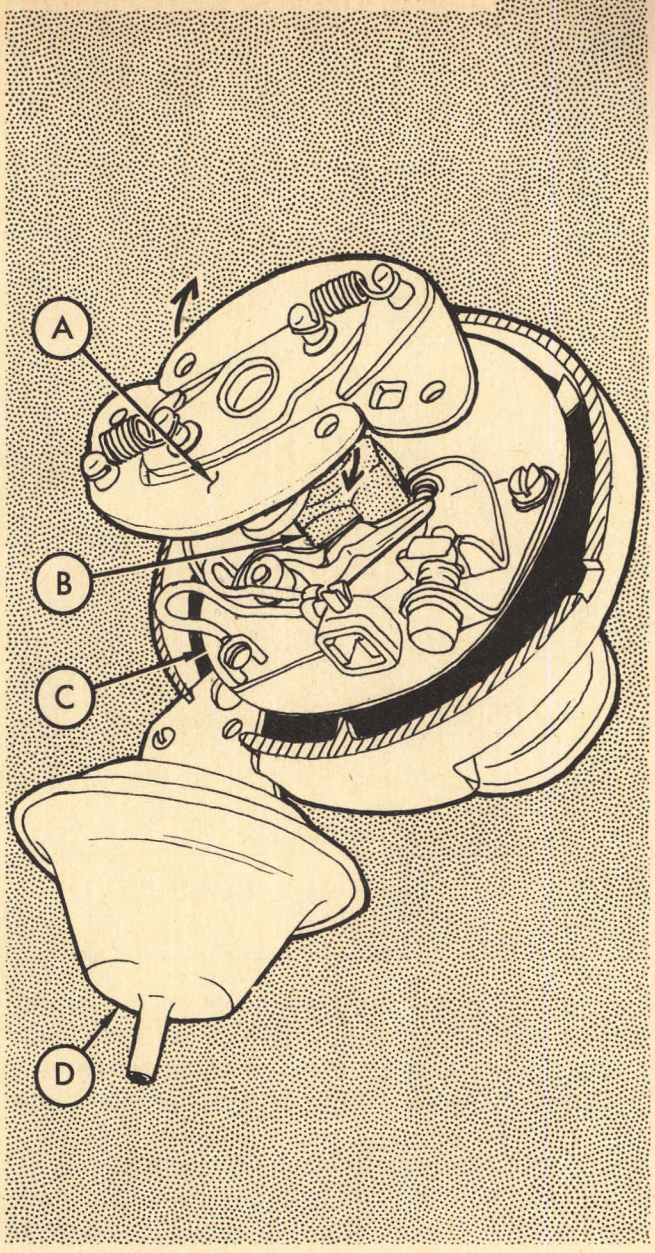
This drawing shows several typical problems that can develop with spark plugs. Many of these can be cured by hand or by cleaning them with a spark plug cleaner, a machine that uses a spray of fine sand driven by high air pressure to remove all deposits. Spark plugs that have suffered some sort of damage should always be replaced.

Some of the problems that spark plugs develop can be clues to other problems. A plug showing a wet, oily deposit (A) indicates crankcase oil is being passed into the cylinders through worn rings, worn valve guides or possibly a ruptured fuel pump diaphragm. A dry, fluffy black coating (B) on the plug tip indicates carbon fouling. This can be caused by a too-rich mixture (an imbalance of fuel to air), a choke malfunction, clogged air filter, most carburetor problems or a sticking exhaust manifold heat control valve. Carbon buildup can also be the result of a weak spark in the ignition system or low-speed driving with long periods of idling. If only one plug is carbon fouled, it's a good idea to check the compression in that cylinder. Also examine the spark plug lead and distributor cap to see if there is a problem associated with that plug.

If the insulated tip (C) of the spark plug is burned or blistered, it can mean serious cylinder overheating. This may be the result of using plugs with an improper heat range, ignition timing too far advanced or a lean mixture (an imbalance of air to fuel). Other problems could be a faulty cooling system or sticking valves.

Residues of the additives in gasoline (D) can build up on the surface of the plug tip after long use. Some of these are good conductors of electricity when hot. If the buildup is not too severe, the plug can be restored by cleaning and re-gapping. But if the coating is too thick, the plugs affected should be replaced.

TESTING IGNITION ADVANCE



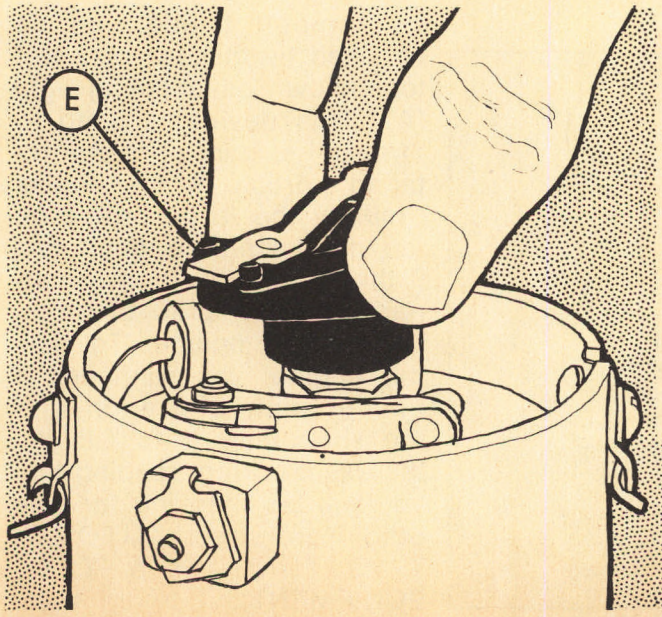
Most distributors have a combination of centrifugal and vacuum advance. The centrifugal advance is a purely mechanical method of advancing the firing of the spark, using weights and springs (A) inside the distributor body. The vacuum advance uses engine manifold vacuum to operate a diaphragm (D) on the side of the distributor housing that advances the firing of the spark plug.

As explained earlier, as engine speed (rpm) increases, the spark for each cylinder must be triggered slightly sooner to allow time for full ignition of the air/fuel mixture before the piston reaches top dead center (TDC) and starts back down on the power stroke. This is accomplished by moving the breaker plate (C), which is the metal plate the points are located on, inside the distributor housing. Since firing time is controlled by the cam (B) on the distributor shaft as it opens and closes the points, moving the plate forward or backward changes the instant in time that the points open and close.

The following are only two rough checks of the advance operation. To completely check advance takes test equipment and knowledge beyond the scope of this book. But these tests will help you find out if your distributor needs to be checked by a mechanic.

NOTE: BECAUSE OF EMISSION (SMOG) CONTROL REQUIREMENTS, THERE MAY BE SEVERAL ADDITIONAL ELECTRICAL CIRCUITS ASSOCIATED WITH THE IGNITION. CHECK THE SHOP MANUAL AND SEE PETERSEN'S BASIC IGNITION AND ELECTRICAL SYSTEMS.

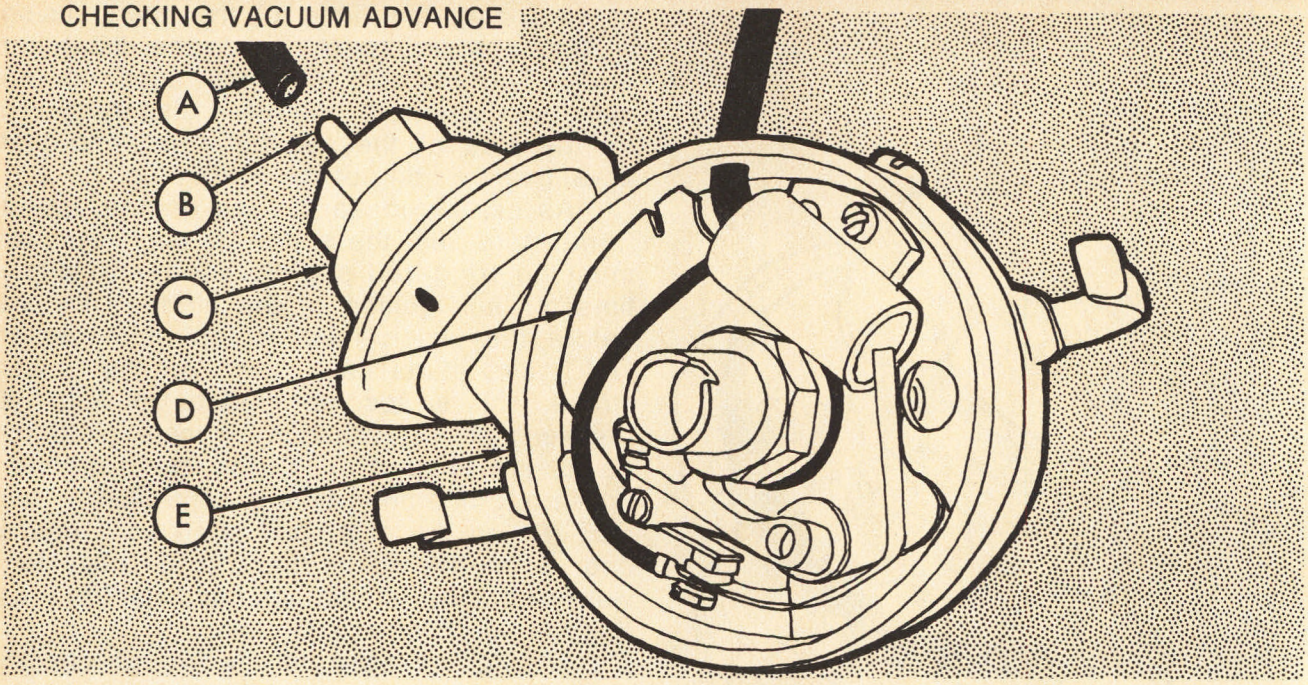
CHECKING CENTRIFUGAL (MECHANICAL) ADVANCE



Remove the distributor cap. Grasp the rotor (E) and see if you can turn it in the same direction that the distributor shaft normally rotates. You will feel the pressure of the advance retaining springs trying to hold the movement back. Let go of the rotor. Check to see if it goes back to its original position easily, without sticking or hesitating. Grasp the rotor again and try turning it in the opposite direction. If you cannot turn it, the mechanical advance is probably good. Actual malfunctions of the centrifugal (mechanical) advance feature are rare.

TROUBLESHOOTING THE IGNITION SYSTEM

CHECKING VACUUM ADVANCE



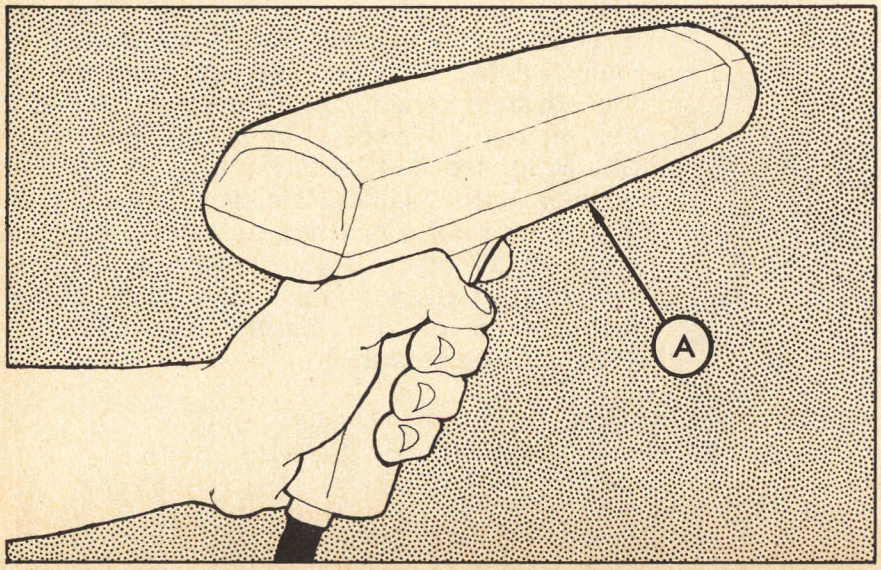
To check the vacuum advance, remove the distributor cap and rotor. Find the vacuum line (A) where it connects to the vacuum diaphragm (C) on the side of the distributor.

NOTE: IF THERE IS MORE THAN ONE LINE TO THE DIAPHRAGM, CONSULT THE SHOP MANUAL TO SEE WHICH ONE IS THE *PRIMARY* VACUUM LINE.

Disconnect the vacuum line and put it aside. Move either the breaker plate (D) or the distributor housing (E—check the shop manual to see which moves by vacuum) as far as you can in one direction. While holding the breaker plate advanced as far as possible, place your finger tightly over the vacuum inlet (B) at the diaphragm. Now let go of the breaker plate. There should be no movement of the breaker plate. Remove your finger from the vacuum inlet. The breaker plate should return smoothly and without binding to its original position.

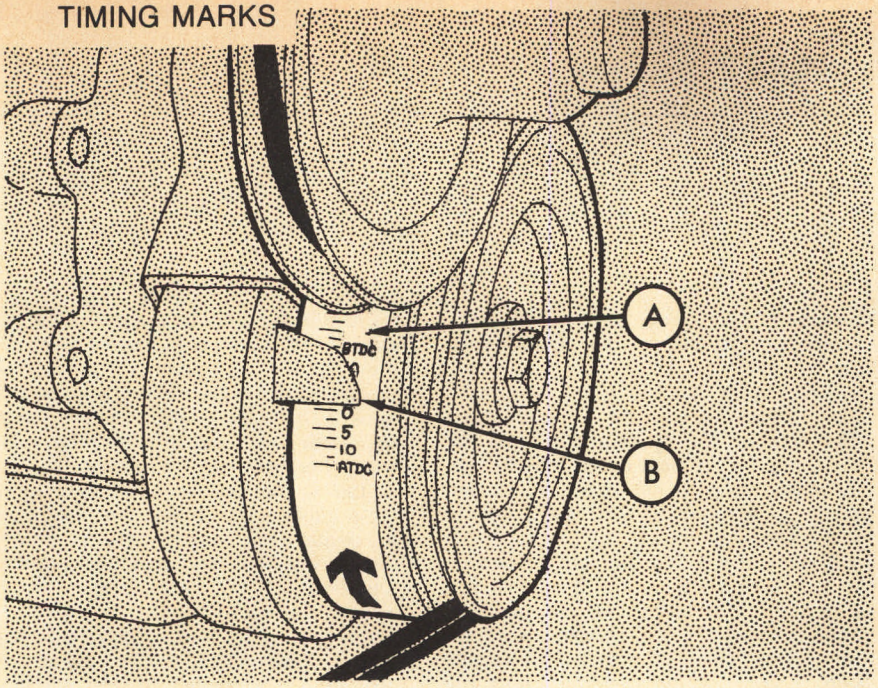
If the breaker plate moves back while you are still holding your finger over the hole, there is a leak in the diaphragm and the unit should be removed and replaced as soon as possible.

THE TIMING LIGHT



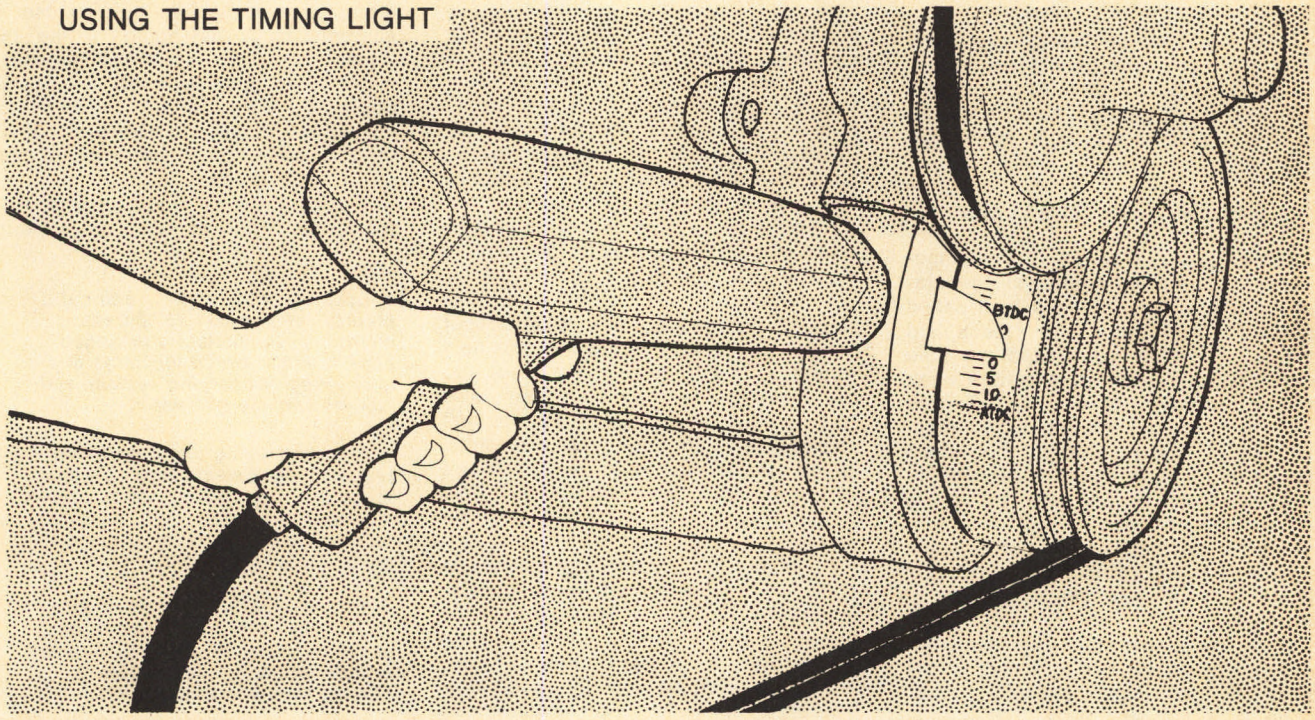
Ignition timing can be checked by the use of a test tool known as a timing light (A). This device is used to "freeze" a mark on some rotating portion of the engine (usually the large pulley on the crankshaft) to determine if the ignition is firing in correct relationship to the rotation of the engine. To time the engine, you will need a timing light, a wrench and the shop manual to tell you the exact correct reading that you will be checking for (see also Petersen's AUTOMOTIVE TUNE-UP & TEST EQUIPMENT).

TIMING MARKS



The timing marks are a series of lines (A) or degree marks with a fixed pointer (B) attached to the engine block or pulley. If the engine is in correct time, each time the number one cylinder fires, the pointer will be aligned with one of these degree marks. One of these marks, usually the center one, will be labeled 0, TDC or DC, to denote Top Dead Center. There will be marks on either side of the TDC mark showing a number of degrees both advanced and retarded from that point. Check the shop manual to find the exact degree timing mark for your car.

USING THE TIMING LIGHT



CAUTION: WHEN LEANING OVER A RUNNING ENGINE, DO NOT WEAR LOOSE CLOTHING OR JEWELRY THAT MIGHT BECOME TANGLED IN THE FAN BELT. AVOID PLACING HANDS OR TIMING LIGHT TOO CLOSE TO FAN BELT OR FAN BLADES.

NOTE: POINT GAP HAS AN EFFECT ON TIMING. BE SURE THAT POINTS ARE IN GOOD CONDITION AND CORRECTLY GAPPED BEFORE SETTING OR CHECKING THE TIMING.

Connect the timing light. When the trigger is squeezed, the pulse of the number one plug will trigger the light. It will flash, showing the relationship of the timing marks to the pointer. By pointing the light at the pointer, you can watch the mark appear to freeze in the flashing light. If the timing is not set according to the shop manual, follow the instructions in the shop manual and adjust it.

Charging System

Would you believe that you could generate electricity just by moving a coil of wire or even a single wire between the ends of a horseshoe magnet? We don't know why it happens, but really there's no need to. As long as we accept the fact that magnetism plus movement will create electricity, then all we have to do is learn how to use it. If moving the wire between the ends of the horseshoe magnet will create electricity in the wire, it seems logical that we might get more electricity if we use two wires. An automotive generator actually uses a lot of wires and gets a lot of electricity, enough to charge the battery and run the car's complete electrical system.

There's another peculiarity about this magnetism and electricity business. Granted: magnetism and movement will create electricity. But it also works the other way around; electricity will create magnetism.

GENERATOR SYSTEMS

Here's the way it works in an automotive generator. The frame of the generator has some coils attached to it called the field coils. In the middle of each field coil is a hunk of iron called the pole shoe. The pole shoes are a kind of weak magnet, probably not even as strong as the little magnets that you use on a magnetic bulletin board. But the magnetism that is in the pole shoes is enough to create electricity in any wire that moves through the magnetic field. The wire in which the electricity is created is in the armature. Of course, the armature has a lot of wires because we want a lot of electricity.

When the engine starts, the generator is turned by the fan belt and electricity is created in the armature because it is rotating in a magnetic field. If the weak magnetic field around the pole shoes was all we had, then we wouldn't get much electricity out of our generator. But a generator feeds itself. The electricity that is created from the armature is fed back into the field coils. This additional electricity strengthens the magnetic field around the pole shoes and causes a greater strength of electricity to be created in the armature.

Now that we have the thing going, electricity in the armature is available to charge the battery, run the lights, blow the horn, or anything else. The problem is getting the electricity out of the armature while it is moving. This is where the commutator and the brushes come in. One brush running on the armature picks up the electrical current and connects to a wire that runs the current out of the generator so that it can be used to operate the car's electrical system. From the light bulb, radio, ignition system or whatever unit is being operated, the electricity returns along a ground path to the frame of the generator and then through the other brush back into the armature. In most cases the electricity must return to its source in a complete circle route. In fact, the word circuit means "circle."

A generator alone can be hooked up to the electrical system of the car and it will put out both current and voltage enough to do the job. But you will have no control over it. The faster the engine goes, the more the generator puts out until it reaches a point where it blows itself right out of the car from trying to put out more than it can stand. An uncontrolled generator will put out 30, 40 or 50 volts, even higher. The car's system is made to run in the area of 12 volts, so we must do something to control the output of the generator if we don't want to burn out all the light bulbs and blow up the radio.

Remember we said that a generator starts putting out electricity because of residual magnetism in the pole shoes. But any electricity above that very small amount depends upon a feedback of current from the armature into the field windings. If the current were not fed back into the field windings, generator voltage would never rise. It just wouldn't charge. To control the generator then, all we have to do is regulate the amount of current that flows through the field windings, and that is the function of the regulator.

Regulation in all modern generators is done with a vibrating regulator. The regulator is set up so that field current runs through a pair of points. Underneath the points there is an electromagnet operated by electricity from the generator. There are two of these electromagnetic regulating units in the regulator, each with its own pair of points. One of them keeps the voltage from going too high, and the other limits the current. If either voltage or current rises above a safe value, the strength of the magnet increases so that the points are pulled apart. The instant the points separate, the generator goes dead because there is no field current. When the generator goes dead, this kills off the electricity it is feeding the electromagnet, and so the magnetism dies and a spring pulls the points back together. The instant that the points come together, the generator is back in business, and then the same thing happens all over again, separating the points.

Any time either current or voltage rises to the preset value, the voltage or current regulator points will start vibrating. Adjustment is by setting the tension on the spring that pulls the points closed. It amounts to a balancing of the two forces—the spring versus the magnetism that tries to pull the points apart. This, combined with the vibrating of the points, results in a system that can be set to current or voltage limits as close as 1/10th of a volt.

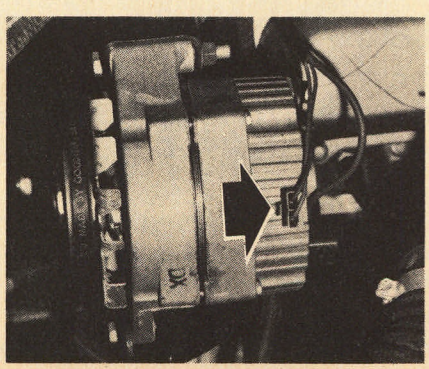
A third unit in all modern regulators is the cutout. If the generator is to charge

1. Look carefully at the electrical plug (arrow) on this 1972 Delco alternator. Contacts are arranged edge-to-edge, which indicates this is an integral charging system, with regulator inside alternator.

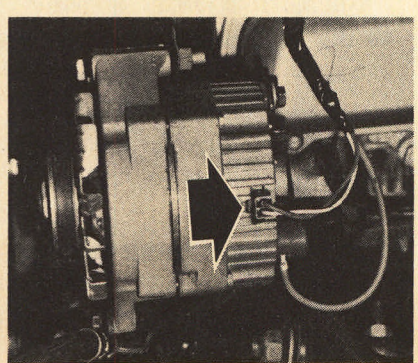
2. Standard Delco alternator (with regulator on firewall) looks pretty much the same, but contacts placed side-to-side are the tipoff. Service on this model is similar to that on older Delco alternators.

3. Inside integral Delco alternator, held by three Phillips-head screws, is the regulator. Diode arrangement is different, too, much easier to change than on older models.

4. These are typical generator mountings on late-model car, showing retaining brackets and belt adjustment provisions.



1. Delco Integral Charging System



2. Delco Standard Alternator

the battery, it must be electrically connected to the battery. If the engine is stopped and the generator is still connected to the battery, current can flow from the battery into the generator in an attempt to turn the generator into a motor. All that the cutout does is disconnect the generator from the electrical system whenever the generator is either not working or is operating at so slow a speed that current would flow from the battery to the generator. When the engine is at rest, the cutout points must be open. Any time the engine is running above idle and the charging system is operating correctly, the cutout points must be closed. If you are lucky enough to have a car with an ammeter that is sensitive to small fluctuations in current flow, you will notice that as you allow the engine to come down to a normal curb idle, the ammeter will go slightly to the discharge side of zero and then it will spring back to the zero position. What has happened is that the generator is turning too slowly to charge the battery, so the battery starts to feed current back into the generator. The minus reading that you see on the ammeter is that current flow back through the generator. But it doesn't show on the ammeter very long because that reverse current forces the cutout to open and then the ammeter returns to the zero position. If your car only has a red discharge light instead of an ammeter, then you can't watch all these fancy goings-on.

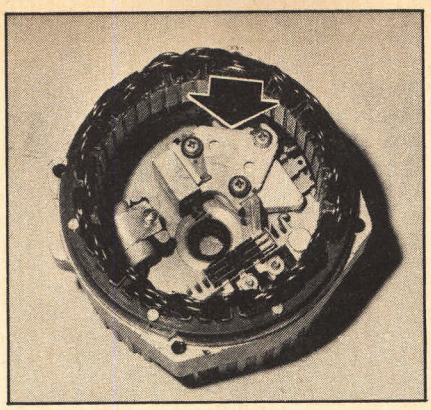
Normal and abnormal charging is far more easily spotted if the car has a dash-mounted ammeter. Usually, the ammeter will show a charge rate of about 7 to 10 amps at normal driving speeds soon after the engine is started. This may be as high as 20 amps following a very long, hard cranking session in cold weather. After the car has been driven for a short distance at highway speeds, the reading should drop to about 2 to 5 amps—depending on how many lights and accessories are in operation. At an idle, the ammeter should indicate no more than a 3-amp discharge, although this may fall to as much as a 15-amp discharge if several accessories are in use. Cars equipped with alternators should seldom show any discharge.

The ammeter needle should never follow engine speed from one extreme of the dial to the other. If it does, the headlights probably also grow very dim proportional to rpm. This condition—or a constant discharge reading, exceptionally high amperage at highway speeds, and conspicuous deviations from the "norms" outlined above—are all signs that the charging system needs work.

DIAGNOSIS AND CORRECTION

Low charging or *no charging* is undoubtedly the most common type of trouble. If the generator light has come on—and stays on—or the ammeter shows a constant and steady discharge, there is no charging taking place at all. If this is accompanied by rising cooling system temperatures, it is probably a broken fan belt, but if the belt is properly tensioned and in one piece, the charging system is the culprit.

A glowing generator light, or an ammeter reading slightly below zero when



3. Delco Integral Regulator

driving at highway speeds, means a low generator output. Once again, this may be only a sign that the fan belt is loose, but if it's not, the trouble is electrical.

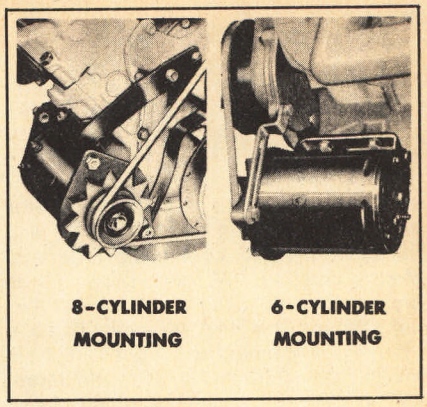
Perhaps you're driving along and the ammeter dips suddenly into the discharge zone and then bounces back a few moments later to a point well up in the charge zone. This shows that the charging system is functioning only part of the time. An "idiot light" that winks on and off as you cruise, indicates the same type of trouble exists. If the light has a slight glow, look for a high-resistance connection at the starter solenoid or the ignition switch.

In some cars, the light will glow at cruising speed even though the entire charging system is in excellent condition. Why does this happen? Well, here's a simple explanation. In the first place, we know that the light is connected between the generator output and the battery, and when the generator is dead or at low rpm its voltage is less than the battery's, so current flows from the battery through the light to the generator. We also know that when the generator is charging, it raises the voltage throughout the electrical system of the car. And since the voltage on both sides of the light is the same, no current flows through it and the light stays off. However, in some cars—and here's our problem—the wire from the battery to the light is too long, and this results in more voltage on the generator side of the light. Because of the unequal voltage, current flows through the light and makes it glow.

You can eliminate the bothersome glow by running a wire directly from the battery terminal of the regulator to the battery side of the ignition switch. This will equalize the voltage and keep the light out. But if you are going to go to all that trouble (and if you're *that* sensitive about your generator), why not install an ammeter so you will really know what's going on? Instructions come with every new ammeter, and they're not hard to install if you follow directions carefully.

Anyway, with a light or a meter, you can still have charging system troubles; with the following series of steps you can diagnose and correct the problem.

Step 1—Examine the Battery. Test it with a hydrometer. If it is fully charged, discharge it by running the starter for a few moments. Then start the engine. If the ammeter shows a normal charge rate it may be that all is well, but probably



4. Generator Mountings

the low-charge, no-charge condition will still be present if the original indication of trouble was a discharge reading and not merely a zero reading. If hydrometer testing shows all of the battery cells to be uniformly discharged, there is a definite charging system problem.

Step 2—Clean the Connections. There is very little use in trying to test the charging system unless you're sure that all connections are making good electrical contact. Sometimes a bad connection can be located with the engine running by having someone watch the ammeter while you wiggle the various wires and terminals that are part of the charging circuit. The connections involved are those on *both* ends of the battery cables (if these are at fault the engine probably won't start anyway), the two terminals on the generator, all voltage regulator connections, and those on the back of the ammeter and ignition switch—as well as the primary (small) wires on the coil and distributor.

Battery cable terminals should be removed and cleaned with sandpaper or a wire brush. Corrosion should be washed away with a solution of baking soda, detergent, and water. Shims can be placed on the battery posts if the cables no longer fit tightly, and new cable terminals installed if necessary. After clamping the terminals in place, they should be lightly coated with vaseline to ward off renewed corrosion. Make absolutely certain that the ground connections are good electrically and, if there is a separate ground strap between the engine and frame, this must also be checked.

Other connections can simply be removed, both surfaces brightened with sandpaper or emery cloth, and the parts rejoined tightly.

Step 3—Eliminating the Regulator. When the battery and connections look good but the charging system still won't put out, the next step is to find out whether the trouble is in the generator or in the regulator. First, disconnect the field wire at the generator itself. You can usually tell which of the two wires connected to the generator goes to the field because it will be slightly smaller than the armature wire. The field terminal may have an "F" stamped next to it, or it may even have a paper ring around it underneath the wire warning that it is the field terminal. This warning, incidentally, is to keep you from connecting any radio condensers to the field terminal. They will really raise heck with the regu-

lator. After disconnecting the field terminal at the generator, fold a piece of tape around it so that it won't ground out and ruin the regulator.

There are two types of circuits that supply the current to the generator fields. One is called the "A" circuit and the other the "B" circuit. Most General Motors cars are "A" circuit, and Fords are usually "B" circuits. In an "A" circuit, ground the field terminal. If it's a "B" circuit, connect a jumper wire from the armature terminal to the field terminal. If you can't remember which circuit your generator has, try grounding the field terminal first and then try it with the jumper between armature and field. With the correct field connector, run the engine to see if the generator will put out. Because you have an uncontrolled generator, you must not run the engine too fast or the generator will put out excessive current.

During the test, all accessories such as windshield wipers or radios should be off so that they won't be damaged. But it's a good idea to turn the headlights on because that tends to draw enough current from the generator so that the voltage will be down a little. You should have a voltmeter to make the test but you can do it by watching the brightness of the headlights if your battery is a little bit weak. On a voltmeter, an uncontrolled generator will show at least 15 volts and as high as 20 or 30 if you're crazy enough to run the engine that fast. If you are going to do it by watching the headlights, watch to see if they get brighter when you rev up the engine. If the generator puts out, and you are still having trouble, it's in the regulator.

Step 4—Generator Removal. Let's assume that electrifying the fields did nothing, and the generator's output remained lower than the hobnails on a coal miner's boot. This means that you must remove the generator from the car for bench testing.

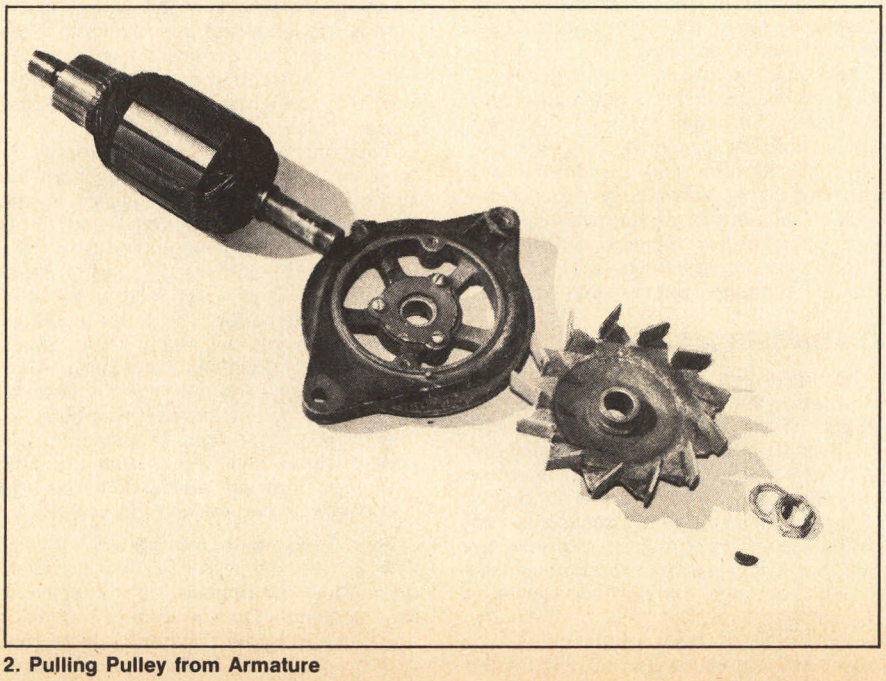
The first step in taking out a generator is to detach the wires from it. Label the wires in some way—perhaps wrapping one with a bit of tape—so that you'll be able to put them back in the same position they were originally.

The generator is supported on the engine by three bolts. You'll have to use a wrench on both ends—on the nut as well as on the bolt—to undo these, but fortunately, the car makers have used different hex sizes for the nuts than they have for the bolts, so you won't need two wrenches of the same size to do the job. Usually the bolts are 1/2-in. and the nuts 9/16-in.—common tool sizes.

Loosen the bolt that fastens the generator to the slotted belt-adjusting bracket first. This will allow you to slip the belt off and swing the generator to a position that makes removing the other two bolts easier. After you've taken the nuts and lock washers off the two mounting bolts, remove the belt-adjusting bolt completely and support the generator with one hand while taking out the mounting bolts with the other. The generator can then be lifted away from the engine.

Step 5—Generator Examination. Once the generator is out of the car, undo the two bolts that hold the brush end plate onto the generator body. These are at the end opposite the fan belt pulley. If the generator has an inspection band,

1. Generator Disassembly



2. Pulling Pulley from Armature

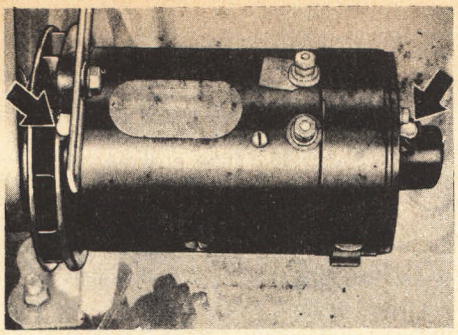
1. Generators will reveal a lot about their condition if you just take them apart and look. In many cases, all that is needed is new brushes.

2. When you get the pulley off the armature, this is what the whole mess looks like. Don't try to slide the front bearing and plate off the armature shaft until you have removed the pulley and the Woodruff key.

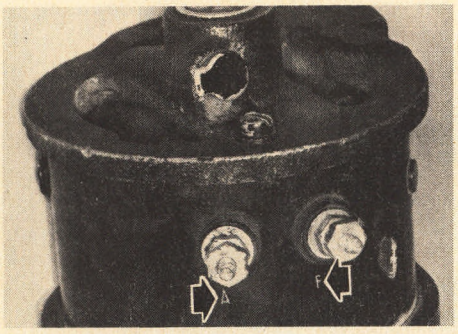
3. Put too much oil in the cup next to the pulley and the only damage will be oil flying out all over the engine, but if you over-oil the rear cup, the excess may flood the commutator and knock out the generator.

4. Generator armature and field terminal points are usually marked, but not prominently. If you can't find any well defined marking, the one with the large-diameter wire should be the armature terminal.

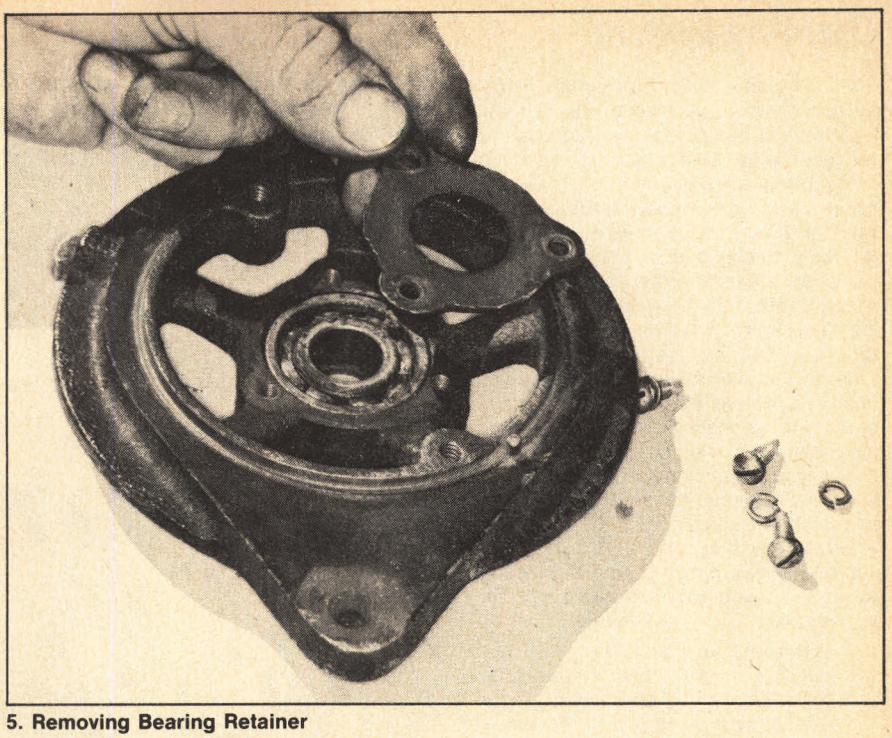
5. After this little plate is removed, the bearing will fall right out into your hand.



3. Generator Oil Cups



4. Terminal Markings



5. Removing Bearing Retainer

this may be removed instead. You should then be able to see the brushes and commutator end of the armature.

The brushes are two graphite-carbon blocks that are mounted in spring-loaded holders. They are pressed by the spring against the commutator—a shiny brass part on the end of the armature shaft.

Check the condition of the commutator while turning the generator shaft by hand. If any of the brass segments are pitted or burned, the armature probably has shorted or grounded circuits and should be removed for testing.

If the commutator is fairly clean, smooth and bright, lift out the brushes and examine them. Brushes that are worn down to a length of 5/16-in. or less are definitely in need of replacement. On the other hand, the brushes may appear to be in good condition. In this case check to see that they slide smoothly in their holders and that the springs are not broken or out of place.

If you've left the generator on the car and are making the examination through the inspection ports in the generator frame, it is often possible to pinpoint brush trouble by pressing down on the brushes with the tip of a screwdriver while the engine is running. If the generator begins charging, the brushes are not making good contact.

Step 6—Servicing Brushes. If the brushes are sticking in the holders, are worn down to minimum length, or the commutator and brushes are coated with grease or a brownish-green glaze, you've probably found your trouble—especially if the ammeter (or "idiot light") indicated a no-charge or only intermittent charging periods.

Greasy or glazed commutators and brushes can be serviced with the generator in the car—providing it has an inspection band. The commutator can be cleaned by inserting a strip of #00 or #000 sandpaper or crocus cloth between it and one of the brushes and rotating the generator by hand until the brass segments are bright and shiny. The sandpaper is then turned over and pulled between the brush and the commutator to make a clean and properly contoured surface on the brush end contacting the commutator.

If the brushes are worn out, new ones must be installed—although an *emergency* on-the-road repair can sometimes be affected by placing a wadded piece of paper between the spring arm and the brush to increase the pressure. Clean the commutator and look closely at the spaces between the segments. If the insulating strips between the segments are flush with the surface of the commutator (or are projecting above it), the armature should be removed and taken to an automotive machine shop for servicing before new brushes are installed. At this time the armature will be checked to see if the commutator is round and concentric with the shaft. If it is not, it will be placed in a lathe and light cuts made across the face of the commutator until the wear is corrected. The insulating strips will then be undercut to a depth of about 1/32-in. using a special tool. You can do this commutator work yourself if a lathe is available and then carefully undercut the insulating strips using a section of hacksaw blade.

The brushes on all modern generators have wires attached to them. It's an easy job to unscrew the old wires from their terminals and fasten the new ones in their place. Give the holders a check to see that the brushes move freely and sand the new brushes to shape by drawing a strip of fine sandpaper under them after they are in position against the commutator. When you put the brush end plate back onto the generator body. be careful not to pinch any wires between it and the generator frame. One of the brushes is grounded to the end plate. The other one, the insulated brush, connects to the armature terminal on the generator. A pinched or grounded wire on the insulated brush or any of its connections will keep the generator from charging and may cause permanent damage. The end plate on a generator usually has a rivet or other projection that fits in a notch on the field frame so that you can get the end plate back in the right position.

If brushes were causing your trouble, you should have it licked now—so put the generator back on the engine, tension the fan belt, and hook up the wires. You're all ready to go!

Step 7—Armature Bench Tests. Back in Step 5 we talked about inspecting the commutator for burned or pitted segments. Actually this is one of two or three possible indications of a shorted, grounded, or open-circuited armature. Loose or broken wires are sometimes visible, and in rare instances the armature may become so overheated that solder will melt from the commutator connections and be thrown onto the inspection band. If severe, either of these last two forms of damage should be cause for installing a new or rebuilt generator. If only one or two wires are loose, they can be resoldered, the commutator turned, and the armature tested for other damage. If none shows, the armature is fit for further use. However, it should be remembered that the damage is probably not due to trouble in the generator, but to a faulty voltage regulator. The regulator should therefore be tested and adjusted or replaced before putting in the generator or its replacement. Otherwise, another generator burnout will probably result. In all probability the original cause of the generator failure was overcharging. The no-charge condition occurred only after the windings had burned out.

If the armature is in really bad shape, there may also be trouble in the field coils. But, in the case of burned and pitted commutator segments, the damage is likely limited to the armature alone. The extent of the damage can be determined with accuracy only by testing both the

armature and the field assembly. Should the trouble be restricted to the armature —or for that matter, to the frame—it may be possible to save a few dollars by replacing only the part needed. However, if the price in your locality turns out to be over half that of an entire rebuilt generator, it's probably best to settle for a complete replacement. When a used part or a used (not rebuilt) generator is to be installed, it should always be tested before being put into the car.

It may be desirable to "farm out" all charging system test work. The majority of automotive machine and supply shops have complete test facilities on hand for this. If you suspect internal generator or alternator defects, the unit can be taken to them for testing and, if it's repairable, you can buy the parts and put them in yourself. If not, they'll be more than happy to sell you another generator or voltage regulator for a reasonable price.

In checking the armature for open, grounded or short circuits, there are several tests that can be conducted:

1) *Open circuits* in the armature are the usual cause of burned segments on the commutator. The burning is produced by an electrical spark that arcs each time the segment connected to the open circuit passes under a brush. Further testing requires specialized equipment not normally available to the home mechanic. Burning is also occasionally caused by oil or grease on the commutator, in which case the generator will begin charging after the commutator has been lathe-turned, undercut, and the brushes sanded to fit.

2) *Grounded cirucits* can be detected with a voltmeter or a battery-powered test light. You can make your own tester using some dry cells, two wires, and a flashlight bulb. Grounded armature circuits are found by touching one test wire to the armature core and the other to the commutator. If the lamp lights, the armature is grounded and must be replaced before further tests.

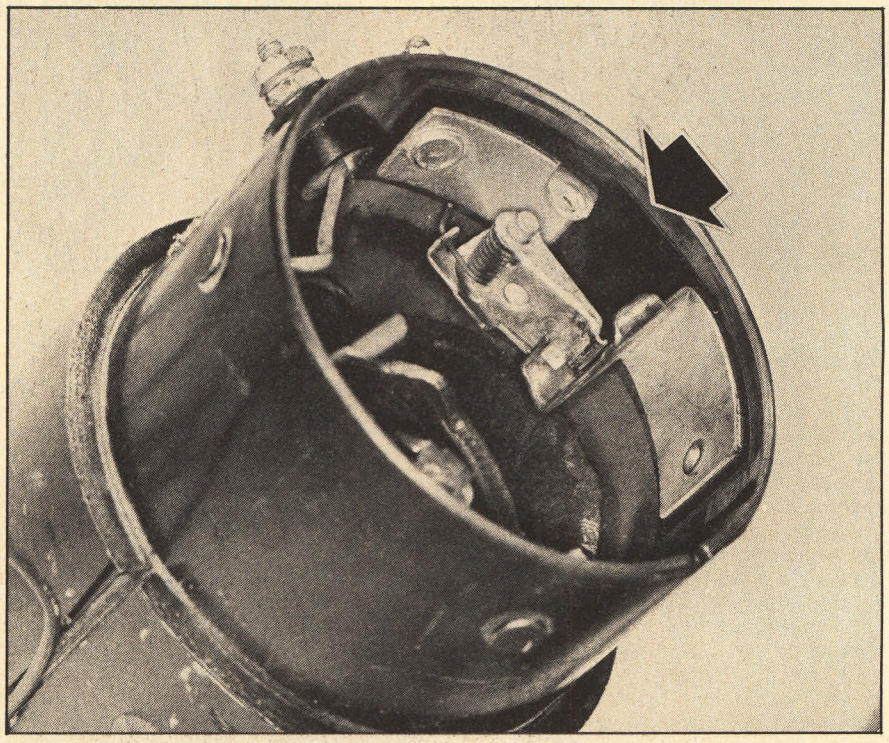
3) *Shorted circuits* in the armature require a test device called a "growler" to locate them—and a bit of experience in its use. If you have this test made, and a short *is* found, you'll have to replace the armature or obtain a rebuilt generator.

In most cases, it's not necessary to take the fan belt pulley and front end plate off the armature while making the above tests. However, if a new armature is to be installed they must be taken off. To do this it is only necessary to undo the large nut at the center of the pulley. It may be impossible to get this nut loose without clamping the armature in a vise. If you do, use soft jaws or two pieces of wood to protect the armature core from damage. You should not attempt to remove the pulley nut by holding the pulley. If you do, the result will probably be a bent or mangled pulley. The only correct way to remove a one-piece pulley is to disassemble the generator so you can put the armature in a vise. The exception to this is the impact wrench method, used mainly by generator rebuilders. Because the armature is heavy, an impact wrench can spin the pulley nut off or on with the generator fully assembled.

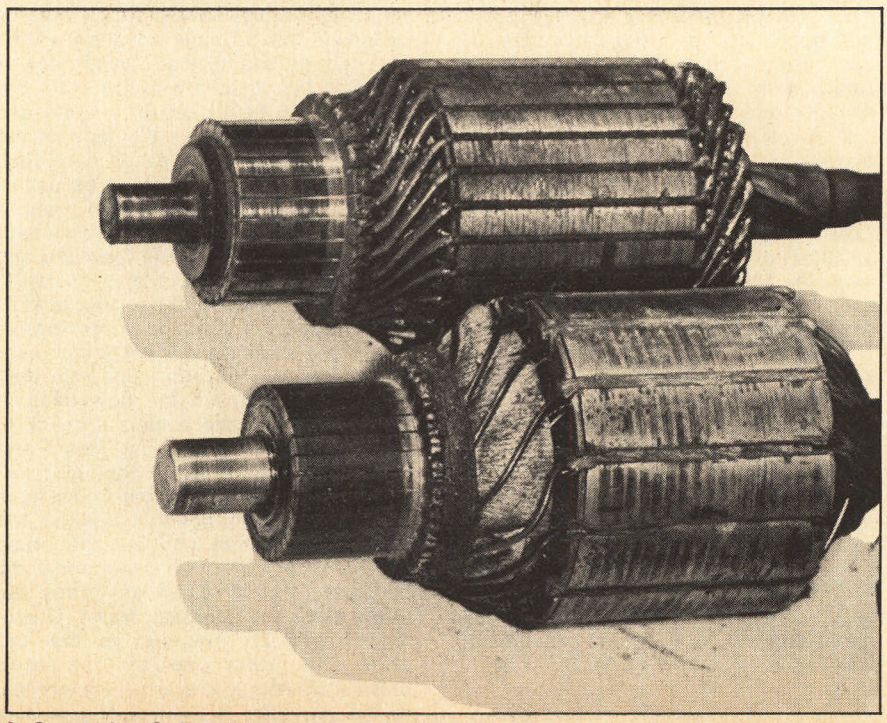
There is a Woodruff key located in a slot between the pulley hub and the generator shaft which you must be careful not to lose as the pulley is slipped off the shaft.

Step 8—Field Coil Bench Tests. Field coils rarely give any trouble. Maybe that's the reason why a lot of mechanics don't know how to test them properly. The field coil, being responsible for creating the full strength magnetic field in the generator, must not have any shorts, grounds or opens. Let's see now what effect each one of these conditions would have on generator output.

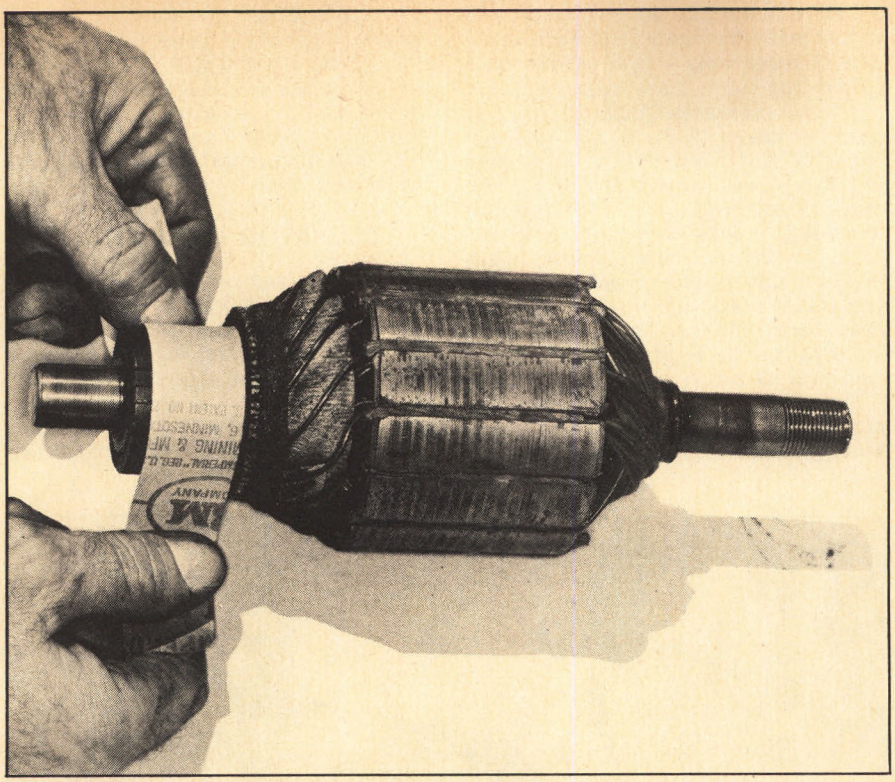
1) *Short Circuits.* Field coils are designed with a certain length of wire wrapped around the pole shoes. This particular length of wire has limited resistance, and therefore it determines how much current will flow through the field coils. If somewhere in the field coil there is a bare wire touching another bare wire, then the distance that the electricity travels will be shortened and we have what is known as a short circuit. A short circuit eliminates some of the wire that the electricity travels through and therefore cuts down on



1. Brush Insulation



2. Comparing Commutators



3. Cleaning Commutator

some of the resistance in the circuit. Less resistance means that more current will flow in the field coils, which burns up the regulator. This situation is rare, but it is one instance where our field electrification test made earlier will get you in trouble. A generator will put out fine with shorted field coils, but the regulator has great difficulty controlling it and eventually burns up.

Shorted field coils cannot be checked with a test light or any other simple instrument. A field current draw test is required and to do it you must have an ammeter that will read accurately to a fraction of an amp. Field current draw on most 12-volt generators is only about 1½ amps. If you can find an automotive electrician who will make the field current draw test for you while you have the generator apart, it's a good idea. However, you must select your automotive electrician carefully. Most mechanics will think you're some kind of a nut if you ask them to make the test. The specifications on field current draw are in the shop manual for your car.

We feel we should warn you about a common mistake made by generator rebuilders, especially with 12-volt Ford generators. It seems that there are a lot of parts floating around a generator rebuilding shop, whether it's big or small. If they aren't careful, they can easily get 6-volt field coils in a 12-volt generator. When you put it on your car, it will do all kinds of crazy things, like charging at idle, or making a buzzer out of the cut-out above idle, with the red light flashing on and off. No adjustment of the regulator will cure the problem, but since the regulator is the part that is acting up, you will probably be sure there is something wrong with it. The problem is that the 6-volt fields are allowing twice as much current to go through the regulator control circuit. Get a generator with the right fields and you won't have any more trouble. You can also get some wild regulator gyrations if the wire that connects the two fields in a Ford generator is grounded out against the through-bolt. In either case, a check of generator field current on the assembled generator would locate the trouble.

2) *Open-Circuited Fields.* This is another rare one, but it's easy to check. All you have to do is trace the wiring in the fields until you find each end. One end will be connected to the field terminal on the generator frame and the other will either be connected to the insulated brush or to a ground somewhere in the generator. To check it, just use a battery-powered test light connected to each end of the field coils. If the light lights, you're in business. If it doesn't, you have a broken wire somewhere and a generator that will not charge.

3) *Grounded Fields.* This is another easy one to check. If the field circuit is grounded in the generator (a "B" circuit), then you will have to disconnect the grounded end in order to make the test. If the field is not grounded in the generator (an "A" circuit), then you don't have to disconnect anything, but be sure that the field lead is not touching the case. To make the test, just put one probe of your battery-powered test light on the field terminal and the other probe on the generator case. If the light lights, something is getting through where it shouldn't, so you'd better find the ground or get yourself another generator. The ground in the field circuit could produce either over- or undercharge, depending upon the design of the system and where the ground was. You can see that checking out the fields correctly is important unless you have so much money that anytime something goes wrong you can throw away the old regulator, generator, and wiring in favor of a complete new system. Admittedly, that is much faster than intelligent diagnosis, but it certainly is expensive.

4. Growler Test

VOLTAGE REGULATOR

Voltage regulators can be a pretty complicated business for the backyard mechanic to handle. In fact, the majority of automotive service garages do very little actual work on them. The faulty unit is simply exchanged for a new replacement regulator.

It would be more expensive for the average customer to have his old regulator tested and repaired than to simply have a new unit installed.

There are a number of safe and simple repairs and adjustments that you can make yourself, and in about 90% of the repairable kinds of regulator trouble, these uncomplicated fixes will cut the ice. If the regulator is so ancient that wear and old age have destroyed the last vestige of its original factory adjustments, the contacts are probably so burned that even the most professional test and repair work couldn't save it. If somebody else hasn't tinkered with them, most regulators will retain their adjustments quite accurately. If something has caused them to go out of balance electrically—such as burned-out resistances—they probably would need replacement, anyhow.

Although commonly called "voltage" regulators, regulating voltage is only one part of their function. After taking out the screws and removing the cover, you will

1. Recognizing the insulated brush is easy. Just look for the strip of insulating material between the brush holder and the field frame.

2. The upper commutator has a normal amount of streaking from the brushes, but the lower one is black from excessive accumulation of carbon, which must be removed by sanding with sandpaper.

3. Many generators will not charge simply because the commutator has an excessive accumulation of carbon from the brushes. A little sandpaper will clean it up nicely.

4. The growler test will find many shorts in armatures, but not all of them. Some will only show up when the generator is running.

see that there are actually two or three coil-like units inside—although some alternator-equipped cars have just one relay.

A closer inspection will reveal that each relay has at least one pair of electrical contacts. Many regulator problems are nothing more than dirt, corrosion, and burned faces on these points. It's not uncommon for moisture to find its way inside the cover and contribute to the formation of a white, powdery corrosion residue that eventually finds it way onto the contacts. In such cases all that needs to be done is a little "house cleaning."

After all foreign matter has been removed from the regulator, the points can be cleaned with a strip of crocus cloth. However, the wires leading to the voltage regulator should be disconnected before you attempt this or other point-polishing operations. If the contacts are conspicuously burned or pitted, you may have to do some smoothing with a point file or fine emery cloth before applying the final polish with crocus cloth. The more mirror-like you leave these surfaces, the less likely future burning is to occur. Following the "sandpaper treatment," the contacts should be cleaned with alcohol to remove any grease or dust that might initiate fresh erosion.

After resurfacing the contacts, the air-gap between them must be set to the correct width. A specification book or shop manual for your particular car will list this under "voltage regulator specifications." Most public libraries have shop manuals on their shelves that tell how to fix particular makes, and one of these may be borrowed to find the regulator specs for your own make and model.

The gap is adjusted with the movable contact held at its widest point. The stationary contact arm is then bent until a feeler gauge of the correct thickness will just slip into the opening. Care must also be taken to align the contact points so that they will meet squarely when closed.

If the contacts have only been cleaned, or polished lightly with crocus cloth, no further adjustment will probably be needed. If more than .002-in. or .003-in. was removed, the spring tension may require some adjustment, but even then only very slight deviations from the original specs are usually found.

Three or four means of effecting voltage regulator spring-tension adjustments are in current use. The most common form consists of a flat leaf spring on top of each unit which presses against an angled metal strip projecting from the frame of the relay assembly. Spring tension is adjusted by bending this piece of metal so that it produces more or less of a deflection in the leaf spring. Another frequently seen type of adjustment utilizes screws that are threaded into the relay frame. These can be turned in and out to change the degree to which the spring is flexed. The last common domestic type employs small coil springs to pull the contacts together. These are adjusted by bending the lower spring hook to increase or decrease the tension on the spring.

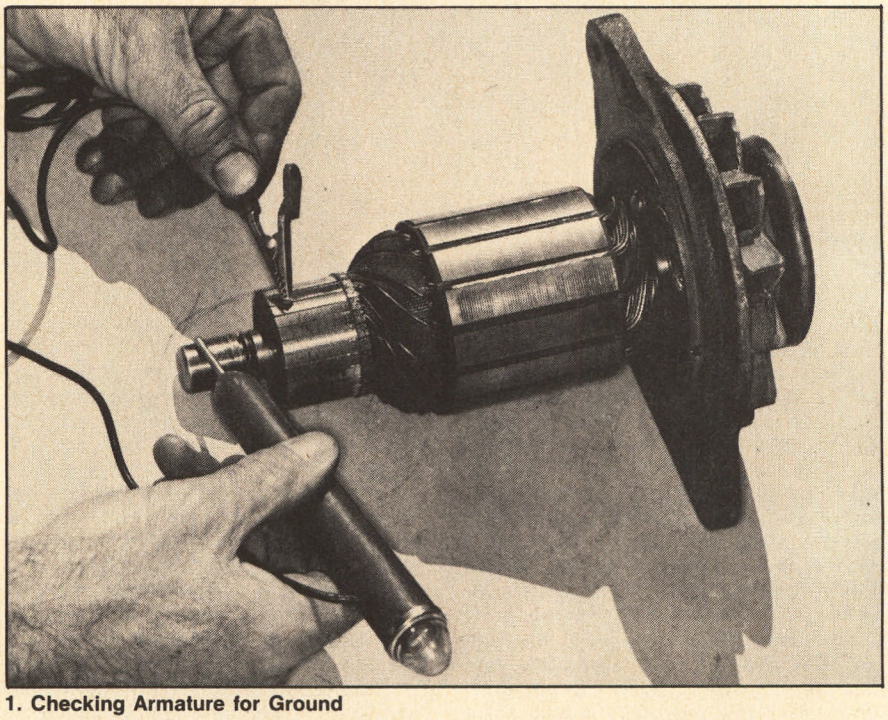
Before adjusting the regulator you should know the function of each relay. One of these units—which all generator system regulators have in common—is the circuit breaker or "cutout." You can spot the cutout by its heavy windings, larger (or dual) contacts, and by the fact that it is located at one end of a 3-unit regulator adjacent to the "BAT" (battery) terminal. It is also the only relay whose contact points are held *open* by spring pressure rather than closed. This relay prevents battery current from flowing "backward" into the regulator and generator when the engine is idling or the ignition is turned off.

The centermost relay is usually the current regulator. It too has a heavy winding, but less of it. The purpose of this unit is to limit the maximum flow of electricity out of the generator.

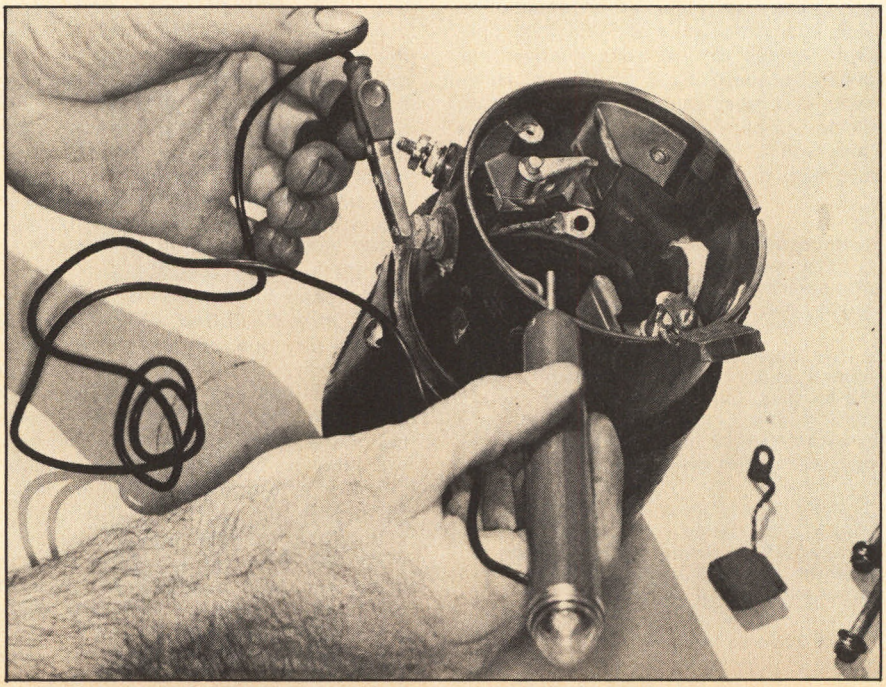
Also, there is the voltage regulator itself. Its windings consist of many turns of fine wire. The voltage regulator relay is a limiter, which protects the electrical system of the car by keeping the voltage below a set limit.

REGULATOR ADJUSTMENTS

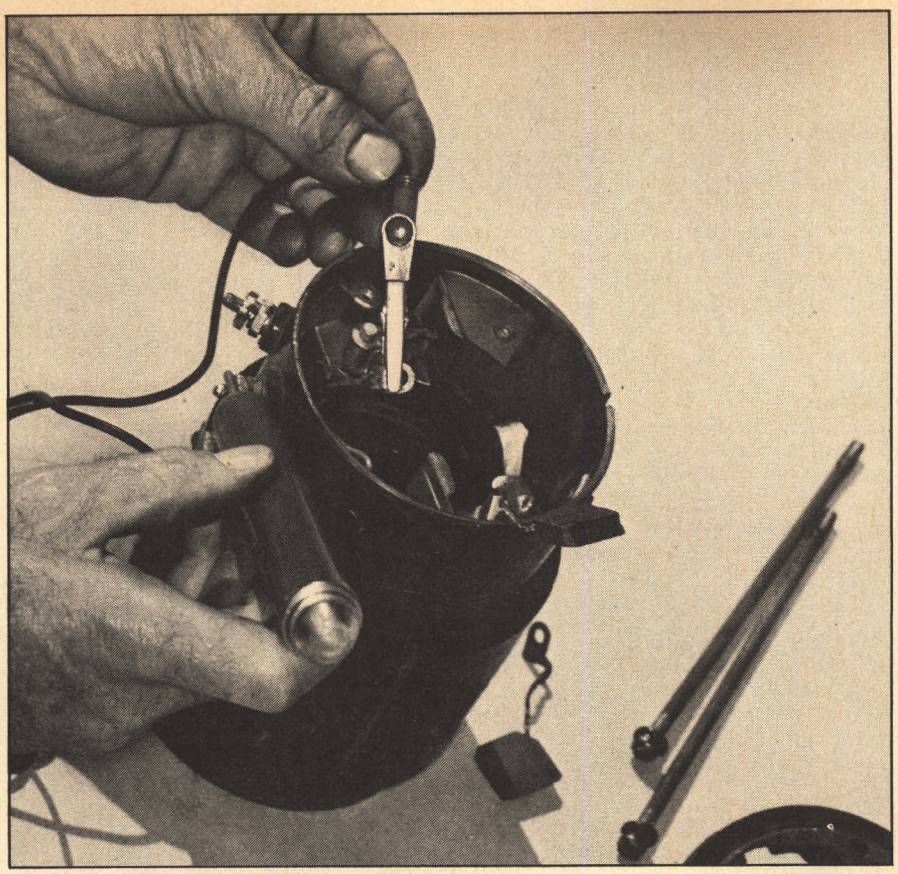
One fault with voltage regulators is that they are too easy to get to. If the car makers would seal the voltage regulator in a fireproof, theftproof box so that nobody could fuss with the darn thing, there would be a lot less trouble with charging systems than there is today. Because the regulator is so easily fiddled



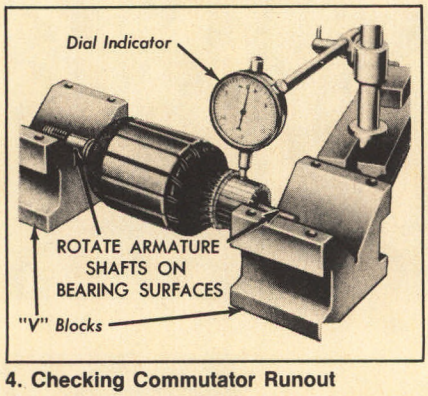
1. Checking Armature for Ground



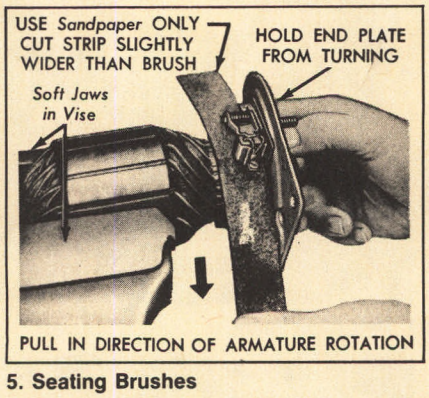
2. Checking Field for Ground



3. Checking Field Continuity



4. Checking Commutator Runout



5. Seating Brushes

1. Checking the armature for ground. If the light comes on, then we know the armature is bad.

2. Checking the field windings for ground. Note that the field lead is disconnected from the insulated brush holder. If a ground shows up, we know that the holder itself is not causing the problem. The stud through the steel frame could also be disconnected to eliminate it as a possible source of a ground.

3. Checking the fields for continuity. The light should come on unless the field windings have a break somewhere.

4. Whenever brushes are changed, the commutator should be checked for runout and smoothness. Turn true in a lathe if necessary. In many cases, mica insulation must be undercut.

5. When new generator brushes have been installed, they should be sanded as shown to assure good initial contact and proper wear pattern.

with, everybody who has a charging system malfunction immediately takes the cover off and starts playing with the thing.

In nine cases out of ten, it's the generator that wears out. Either the bearings go bad, the brushes wear out, the armature flies apart, or maybe even the belt is loose. But in spite of that, everybody goes directly to the regulator and starts playing with it. We want you to know how to make regulator adjustments, but you'll be a lot happier and better off if you will concentrate your efforts on the generator and be positively sure that it is OK before you start working on the regulator. Adjusting a regulator is not difficult, but you have to have a delicate touch—and an accurate voltmeter and ammeter. Let's take a look at the three units in the regulator, one at a time.

1) *Voltage Regulator.* The voltage unit is a limiting device. It doesn't do a thing until the voltage gets up to the point where it might damage the electrical system. Then the voltage regulator cuts in and keeps the generator from burning out all of the light bulbs.

A generator does not put out full voltage all the time. One of the characteristics of an automotive generator is that it cannot put out maximum voltage and maximum amperage at the same time. When it is putting out maximum current or amperage, the voltage falls to a comparatively low level. When the generator is putting out maximum voltage, there is practically no current flow at all.

A generator is somewhat like a city water system. It supplies current and voltage to all of the electrical units in the car in the same way that the big water pump down at the city water works supplies water and pressure to all the homes in town. If everybody turns on the faucet at the same time, the pressure will drop but the flow of water will increase so that everybody gets an adequate amount. If only a few people have the faucet turned on, then the pressure builds up while the flow of water is considerably less.

The automotive generator works the same way. When you have a lot of accessories on—headlights, radio, air conditioner—then the voltage falls because the generator is supplying a lot of current. When you turn everything off except the ignition, then the generator voltage rises and charges the battery until the battery gets up to a full charge, at which time the generator voltage tries to rise above the fully charged battery but is prevented from doing so by the voltage regulator. This is the only time that the voltage regulator actually works—when the generator is operating at high voltage, as it would against a fully charged battery.

In order to test the voltage regulator, we either have to have a fully charged battery in the car or we have to fool the generator into thinking that there is a fully charged battery in the car. This fooling process is done simply by inserting a ¼-ohm resistor in the line between the generator and the battery. Some of the tune-up equipment companies make ¼-ohm resistors, and sell them for use with an ordinary voltmeter, but most of the generator testing in garages is done with a volt-amp tester, which has the resistance built into the unit. The resistor limits current flow the same way a fully charged battery would, and the generator voltage rises to the point where it is controlled by the voltage regulator. With a ¼-ohm resistor in the line and the engine operating at about 2000 rpm, all you do is take your voltage reading off the armature terminal either at the generator or at the regulator, whichever is most convenient. The reading you get will be the voltage as limited by the voltage regulator.

Some regulators have double contacts in the voltage relay. One pair of contacts is called the series set, and the other the shorting set. In Delco-Remy regulators, the series set is the lower one, and the shorting set is the upper one. In Chrysler and Ford regulators, the position of the two sets is reversed. When the regulator is limiting the voltage at low speed, and the generator output is low, the regulator vibrates against the series contacts. At

high speed, and close to zero output, the regulator vibrates against the shorting contacts which results in about 1/10- to 1/2-volt less than when the series contacts are used. A 1/4-ohm resistor used with a double contact regulator will check the shorting contacts. To check the series contacts, about 10 to 15 amps must be allowed to flow which means you must remove the 1/4-ohm resistor and put a light load on the system. The process is admittedly tricky, but modern volt/amp testers will do it with just a few twists of a knob. However, the difference between operation on the series and shorting contacts is so small, that a quick check of the system voltages with the battery operating against a 1/4-ohm resistor (or a fully charged battery) is usually sufficient. The purpose of the double contacts is to ensure more precise control of voltage, and longer contact life. Changing the voltage setting is the same on either single or double contact units.

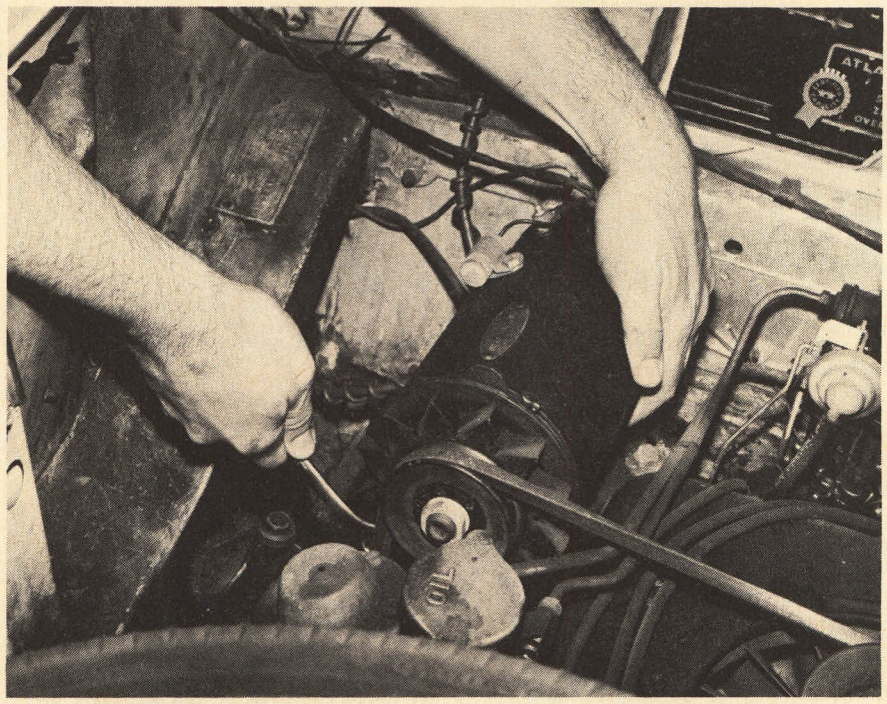
To increase the setting, you merely increase the spring tension that holds the points together on the voltage unit. If the voltage is too high, a little less spring tension will lower it. It takes a delicate touch because a very slight change in spring tension will give a big change to the voltage. It also takes certain precautions to keep from burning everything up. You should shut the engine off and disconnect the battery ground cable before you take the cover off the regulator, because if you accidentally move the cover sideways while you are taking it off you can easily ground out something and burn up the regulator.

After making each adjustment, the cover must be in place on the regulator because it holds in the heat and also has an effect on the magnetic field. When you fire up the engine, you can see on your voltmeter the change that you have made, but it's a good idea to allow the engine to go back down to idle so that the cutout opens. Then bring it up again and check to see if the reading is in the same place. Allowing the cutoff points to open like this is called "cycling the regulator," which gives it a little exercise and helps stabilize the reading you get.

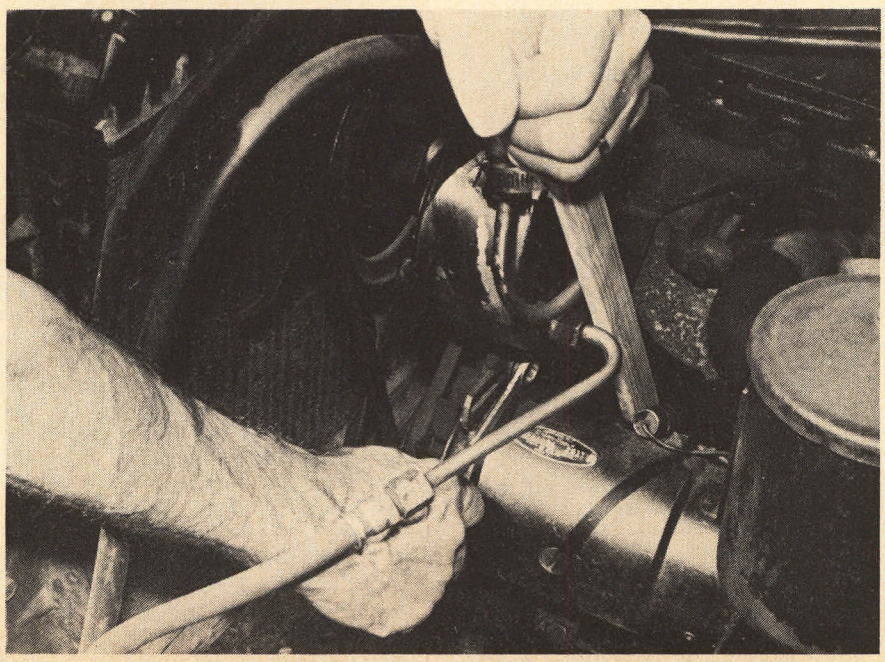
2) *Current Regulator.* To check the current regulator we must have maximum current flow out of the generator to find out if the current regulator will limit the flow to a safe value. We don't want the ¼-ohm resistor in this case, but we do have to disconnect the battery wire at the regulator anyway in order to insert leads from the ammeter. A test ammeter is always connected so that all of the electricity flows through the ammeter or the shunt that is part of the ammeter. With the ammeter connected and the engine running, we turn on as many accessories as we can in order to get maximum current flow. If you don't have enough accessories to get a large current flow, then you can crank the engine a few times in order to run down the battery a little.

If you get enough load on the generator, the current flow will rise high enough that the current regulator unit will regulate it. Current regulation is necessary for only one reason—to keep from burning up the generator. The generator is peculiar in that the faster you turn it the more it will put out. It can easily burn itself up if it doesn't have the current regulator in the system to protect it. If your car does not have a lot of accessories and you always keep your battery in good condition, it's possible to drive for several years without ever needing your current regulator. The current regulator is adjusted the same way that the voltage regulator is—simply by increasing or decreasing the spring tension on the points.

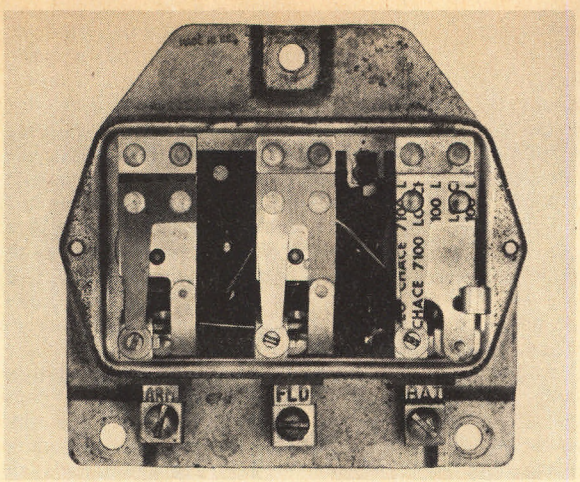
3) *Cutout.* If we didn't have some way to disconnect the generator from the battery when the engine was idling or not running, the battery would discharge back through the generator and be dead in a few hours. Any time the engine is idling or not running, the cutout points are open, disconnecting the generator from the battery and the rest of the car. A generator is a self-generating device, so the minute it starts turning it puts out current and voltage. The current goes up through the wire to the voltage regulator, but it can't get any further because the cutout points are open. However, some of the current is taken from the wire through the cutout coil and directly to ground. The cutout coil thus acts as an electromagnet to close the cutout points. The electromagnet overcomes the spring that holds the cutout points open. We can adjust the spring tension so that the cutout will close at any voltage we de-



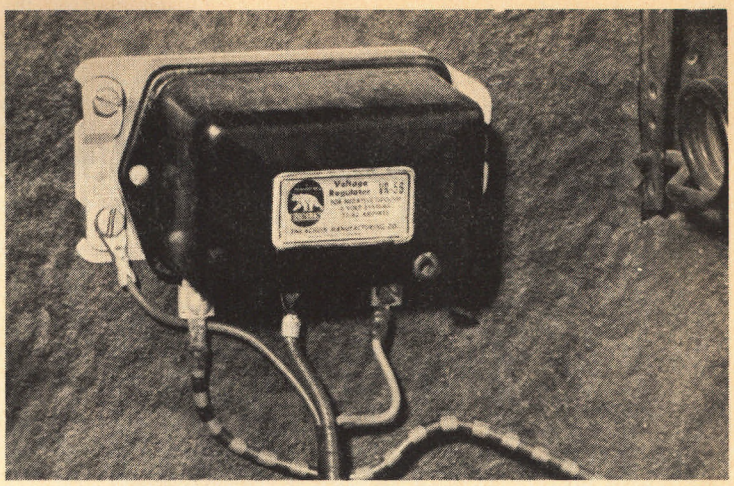
1. Belt Adjustment



2. Tightening Belt



3. Three-unit Regulator



4. Regulator Wiring

sire. Cutouts are usually set about 1 volt above normal battery voltage. Thus, a 12-volt system with normal battery voltage of 12.6 would have its cutout set at approximately 13.5 volts. As long as the generator is operating at a normal or high speed, the cutout points will remain closed because current flows at all times through the cutout coil. However, when the generator speed falls down to a slow idle or the engine is shut off, current immediately runs from the battery to the generator in a reverse direction through the cutout coil. Because the current is now running in a reverse direction through the coil, it reverses the magnetism in the cutout and forces the points open. The current that forces the points open is called the reverse current, and it can be measured with your ammeter in the circuit. Reverse current usually runs less than 5 amps. If it takes any more than that, the cutout points are probably sticking.

There is very little that can go wrong in any of the three units in a regulator. They are adjusted accurately at the factory, and ordinarily they will stay in adjustment through many years of use. The only weak element in a regulator is the points themselves. They pit and the point surfaces get so bad that they won't conduct electricity any more. If you get in there with a riffler file and really clean out the points well, you can reset the regulator and probably get another 5 years of service out of it. If you do file away a lot of metal to get the points clean, it will be necessary to set the point gap and also the air gap between the armature and coil.

You can see that the adjustments on a regulator are somewhat complicated, and this is the reason that very few adjustments are ever made in commercial garages. It's much easier to throw the old regulator away and put on a new one. New regulators that are made by major companies are usually adjusted perfectly at the factory and do not require any checking or adjusting when they are installed. If you buy a rebuilt regulator, or one that is not a major brand, you had better check it carefully to see if it's in adjustment.

ALTERNATOR SYSTEMS

In order to be precise both generators and alternators produce alternating current, and therefore might properly be called alternators. Yet, their electrical circuitry and construction features make them as different as boys and girls. The brushes of a generator are arranged so that the current reaching the armature is always of the same polarity. This is really quite inefficient, since only a small part of the generator's armature windings are producing useful energy at any one time. The rest are just waiting their turn and placing a drag on the engine's horsepower. Having a relatively low output for its size, the generator is often unable to supply the current demands of modern cars equipped with many electrically operated accessories. This shows up especially in city driving where you'd best not try to use the heater, lights, wipers, and radio all at the same time, or you might not start up next morning.

Alternators will produce usable electricity from *all* of their windings *all* of the time. Thus, they can be smaller and lighter, yet still put out almost full voltage even with the engine at an idle. Alternators do this by using some ingenious little devices known as rectifiers. A rectifier is a small disc formed from a substance that has the highly unique property of allowing electricity to flow through it freely in *one* direction, but not in the other.

The rectifiers—there are six of them—are divided up into two groups of three each. One group allows a steady flow of positive-polarity electricity to pass through while rejecting negative current. The other group permits the passage of negative current while rejecting the positive current.

The diodes—another name for the rectifiers used in alternators—can be burned out almost instantly if current of the wrong polarity is accidentally routed into them. One of the most common causes of "sudden death" among diodes is the incorrect use of jumper cables to start balky cars in winter time. Some cars have the positive pole of the battery grounded while others have a negative ground system. Frequently, someone will unthinkingly connect a booster cable from the positive side of his battery to the negative pole of the other car. Zap! —no more diodes.

A *no-charge* condition is, of course, the most frequently encountered charging system trouble. Your first action should always be to check for the obvious. Has the fan belt broken? Is it loose and slipping? A quick glance at the water temperature indicator may give you the answer. If a no-charge is shown by the glowing indicator light, but the battery is fully charged, there is probably just a bad connection in the indicator light circuit. A careful inspection under the hood, giving special attention to the battery cables, wiring and drive belts, should eliminate many of the possible causes of the failure. But if all proves to be in order, there are still other easily-checked items that can solve your problem—or at least point to the correct solution.

ELIMINATING THE REGULATOR

If the alternator system isn't working properly, the first thing to check is the battery. Be sure it's right before you go any further. When you are sure that the trouble stems from undercharging, overcharging, or no charge at all, it's time to determine whether the regulator or the alternator is at fault.

A generator creates its own field current, but an alternator receives its field current from the battery. There are several different circuits, but in most of them current flows from the battery, through the ignition switch, through the regulator, and into the alternator field. The regulator controls the alternator by

1. You may have to adjust the belt tension two or three times until you get it to where it's exactly what you want. New belts will stretch, so check them again after about a half hour of running time.

2. If generator must be pried against to adjust fan belt tension, use a piece of soft wood. Make sure belt has correct degree of side play as specified in owner's manual.

3. Typical 3-unit regulator, with voltage, current, and cutout relays. Point spring tension on this model is changed with screws.

4. Wire going to base of regulator is merely a ground to insure that the regulator points will work correctly. It's a good idea.

cutting down on the amount of current that goes to the field. Transistor regulators are different, and we suggest that you leave them to the experts, because it is very easy to blow a transistor if you hook testing leads in the wrong places.

To eliminate a mechanical regulator from the charging circuit, all you have to do is disconnect the field lead at the alternator and attach a hot lead directly from the battery. You will then have full field current. Make sure all the accessories in the car are off, then start the engine and take a reading of the voltage at the alternator output terminal with the engine idling. If the battery is fully charged, you will get 14 volts or more at idle. If the battery is low, you may have to increase the engine speed slightly above idle. Either way, if you get 14 or 15 volts out of the alternator, you can be pretty sure that it is OK, which means the trouble must be in the regulator. Revving the engine to produce more than 15 volts is unnecessary, and may blow some part of the electrical system. Never run an alternator with the output wire disconnected. They will put out 200, or even 300 volts, which is enough to fry the alternator and maybe a few other units as well. If the alternator does not put out 15 volts in this test, then there is something rotten inside it. The regulator may also be bad, but you can't check it out until you know the alternator is doing its job.

ALTERNATOR BRUSHES

Yes, Virginia, alternators *do* have brushes—and one of the nicest things *about* alternators is that many of them can have the brushes quickly removed and checked without taking the unit apart or removing it from the car. This is true of all Chrysler alternators, as well as the larger GM and Ford units. Sticking or worn-out brushes are a common source of trouble.

There are two brushes in an alternator. They are located in the alternator housing on the end opposite the V-belt pulley. On Chrysler Corporation units, one brush is mounted in an insulated plastic holder that has the alternator's field terminal attached to it. The ground brush is mounted separately in a metal holder that is screwed onto the alternator end housing. Taking off the field wire and removing the Phillips-head screws from the holders will get the brushes out and into your hands quicker than you could spend $10 on a spree in Tijuana.

GM's Delcotron alternators employ two systems of brush mounting. On the larger types, the brush holder—complete with the two brushes, the alternator terminals and a capacitor—can be taken out simply by removing all the wires and undoing two regular screws. The small 5½-in. Delcotron must have its four through-bolts removed and the end housing taken off before you can get at the brushes. The alternator should be removed from the car to do it, but some mechanics have found out that they can remove the end housing with the alternator still mounted on the engine. They don't even remove the belt. It's a neat trick if you're in a hurry.

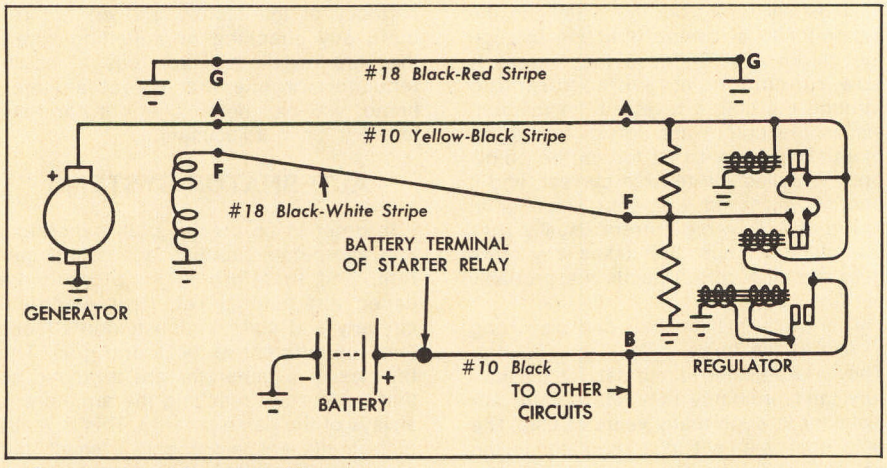
The larger Ford alternators have two separate brush holder assemblies that are threaded so that they may be screwed directly into the alternator's end housing. These are easily removed using a wrench on the large hex at their outer ends. Like the small GM units, Ford's little ones must have the end housing taken off before you can work on the brushes.

On the Chrysler units it is sometimes possible to locate brush trouble by loosening the holders slightly and wiggling them while the engine is running. If the ammeter needle jerks up into the charge range, or the "idiot light" winks while you are doing this, you are on the right track. But remember one thing when working on the alternator or generator with the engine running. Those fan blades going around between the engine and the radiator may be invisible, but they're still plenty solid! Don't become so interested in what you're doing that you accidentally saw off a finger.

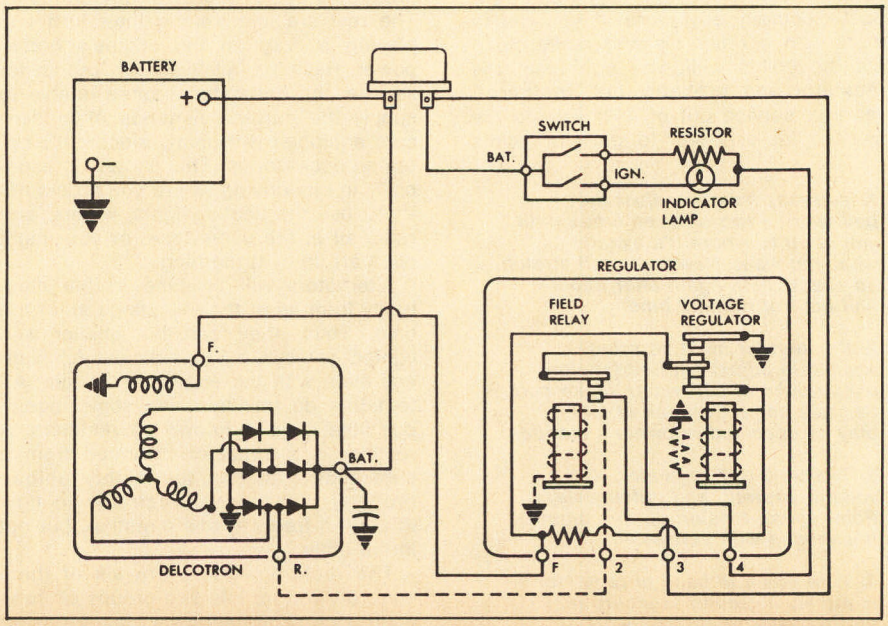
ROTOR TESTING

If you have a testing ammeter available, you can make a further check before disassembling the alternator that will show up trouble in the brushes and slip rings, or perhaps point to burned-out rotor windings. You can take the alternator out of the car for this test if you want to.

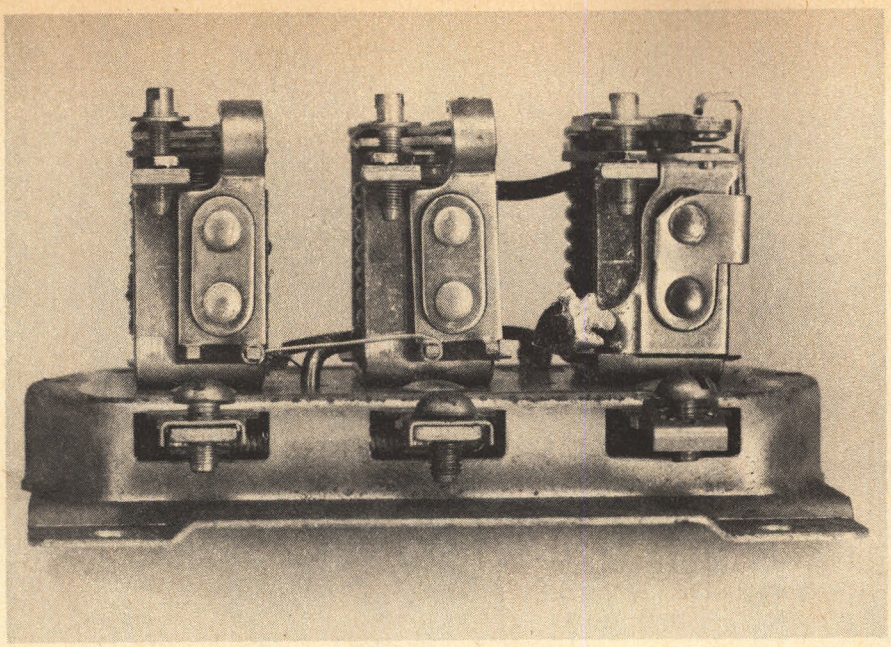
Disconnect both wires from the alternator's terminals. Connect the ammeter's positive lead to the battery's positive terminal. The battery must be fully charged. Attach the other ammeter lead to the alternator's field terminal. As mentioned earlier, this is on the insulated brush holder of Chrysler products. On most alternators it is marked "F" or "FLD." Connect a jumper wire from the battery's negative pole to the frame of the generator—although this is not necessary if the alternator has been left mounted on the engine. Turn the alternator shaft slowly by hand. The ammeter should indicate a field coil draw of between about 2.3 and 3.0 amps at 12 volts—depending on the make and model car. A lower reading indicates a high resistance in the circuit, which means poor electrical contact between the brushes and the slip rings, or maybe even a faulty field winding. Higher-than normal readings indicate that there's a possible ground or short in the rotor coil.



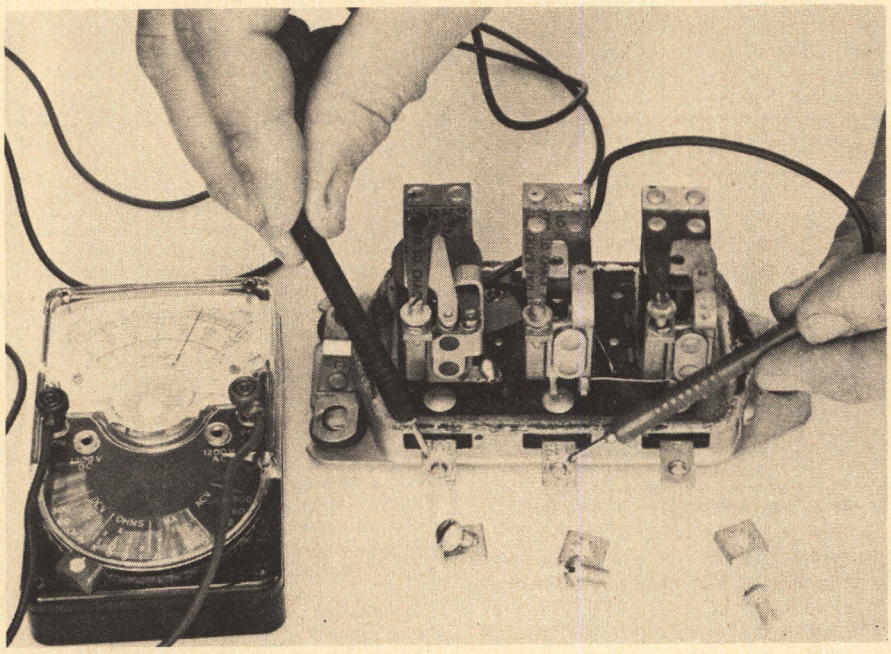
1. Generator and Regulator Wiring



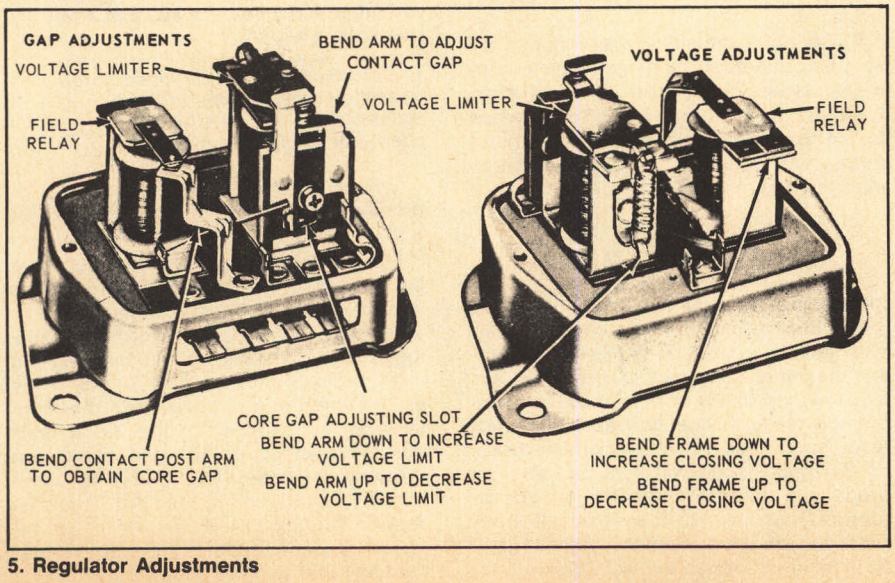
2. Alternator and Regulator Wiring



3. Screw-type Adjustments



4. Testing Cutout



5. Regulator Adjustments

Most ammeters are not accurate enough to read to 1/10th of a volt. So it isn't practical to measure field current draw unless you have an accurate ammeter. If you do get an ammeter that will measure in tenths of a volt, be very careful when hooking it up. An accidental ground can burn out a low reading ammeter very quickly. It's a good idea to hook up your ammeter in series with an adjustable rheostat just in case current draw might be excessive.

If you haven't guessed it by now, the difference between a generator and an alternator is the location of the magnetic field and the wires in which the current is generated. In a generator we have a wire rotating in a magnetic field. An alternator is just the opposite, with a magnetic field which rotates inside of a coil of wire. When we measure field current in an alternator, we are measuring the amount of current that flows through the rotor coil which rotates in the center of the alternator. Brushes last a lot longer in an alternator because all they are required to carry is the small amount of field current, whereas in a generator they must carry all the current a generator produces.

Current in the alternator is produced in the stator, a heavy coil of wire that encircles the rotor. Because the stator has so many more loops in it than there are in a generator armature, the alternator will put out current at a much lower rpm than the generator. Alternators will charge at a normal curb idle. Some of them—the heavy-duty ones used on police cars—will even put out 100 amps at idle. And the alternator has another advantage in that it does not need a current regulator because it is self-limiting. You can spin it as fast as you want to and it will only put out so much current, so there's no danger of burning it up.

Alternators are a lot easier to work on than generators, once you get the hang of installing the brushes. Some alternators require that a small pin or drill be inserted to hold the brushes in place while the alternator end-frame is being put in position. Many alternators are designed to work with only a single unit regulator which controls voltage. A cur-

1. This diagram shows the relationship of the generator to the voltage regulator and battery in a Ford system, which has the field grounded at the generator, known as a "B" circuit.

2. General Motors has several wiring setups, all using the same alternator. This schematic is for an indicator lamp (idiot light) with field relay.

3. Cutout at right has normally open points. The others are normally closed. Note lock nuts on adjusting screws.

4. A shorted cutout can be found by testing between the "BAT" and "GEN" terminals. If an ohmmeter reading is obtained, the unit is faulty.

5. Field relay in Ford regulator rarely needs adjusting. A special bending tool is recommended, but pliers will work when adjusting regulators with bendable posts.

rent regulator is not needed because the alternator is self-limiting in its current output. A cutout is not needed because the diodes themselves prevent any reverse current flow from the battery. There is a certain amount of drain through diodes because they are not perfect, but normally it would take several months before the diodes would discharge the battery completely, so the current drain is not enough to worry about. Besides the voltage units, some regulators have a relay which may be used to feed current to the field, to turn out the light on the dash, or to do both these functions.

REMOVING THE ALTERNATOR

On most cars, the alternator is an easy component to remove. It is often mounted high up on the engine and, unless buried under a maze of power accessories, even the low-mounted ones are easy to pull. After disconnecting all wires from the alternator and labeling them for future replacement, the bolt holding the alternator to the slotted belt-tensioning bracket can be readily loosened. Two wrenches—one for the nut and one for the bolt—must be used. Once the bolt is loose, swing the alternator into the position that makes reaching the other two bolts easiest. When the nuts and lock washers are off these, the adjustment bolt can be taken out and the alternator supported by hand while the remaining bolts are taken from mounting brackets.

ALTERNATOR TESTS AND REPAIRS

When disassembling the alternator, it is necessary to first remove the brushes and holders on those units which do not require dismantling to do so. The bolts or screws holding the end shields can then be removed and the housing pried apart gently with a screwdriver. You will then have complete access to the rotor, stator and diodes. With the help of a battery-powered ohmmeter or test light the following tests can easily be conducted:

1) *A grounded rotor* may be detected by touching one test lead to the rotor shaft and the other to each of the slip rings. If the ohmmeter reads low, or the lamp lights, the windings are obviously grounded and a new rotor is required.

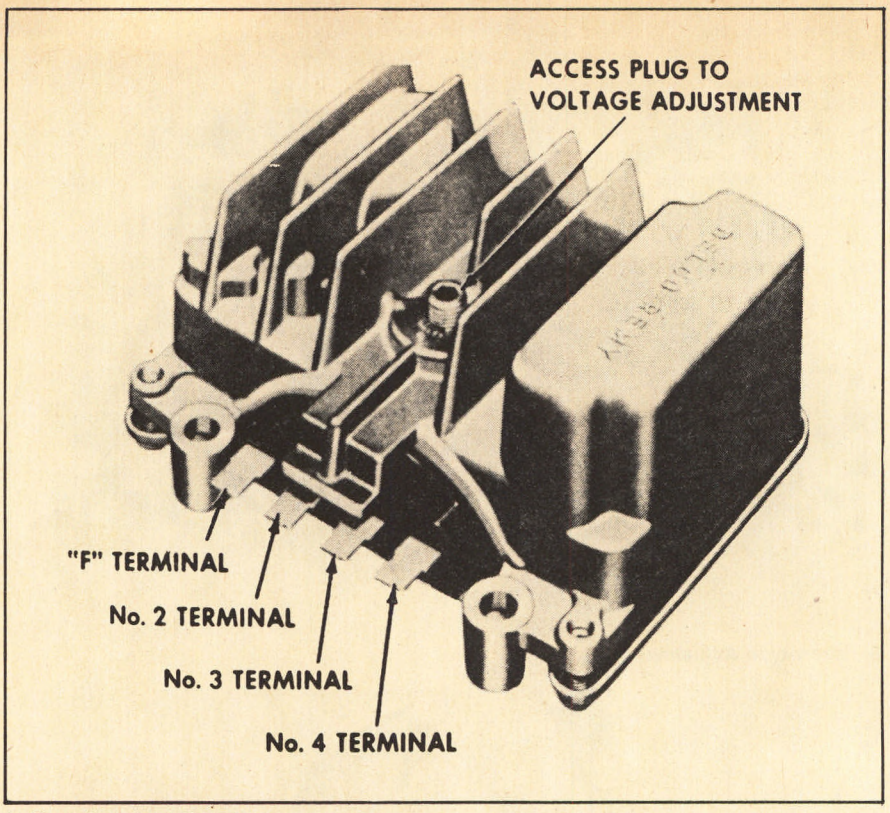
2) *Open circuits* in the rotor are found by touching one test light lead to each slip ring. If it does not light, the windings are open and the rotor unit must be replaced.

3) *A shorted rotor* can be checked with an ohmmeter or a low reading ammeter. As most rotor specifications are given in current draw, the usual way of checking for a short is with the ammeter. The same technique and cautions apply as when checking field current draw on a generator, covered earlier in this chapter.

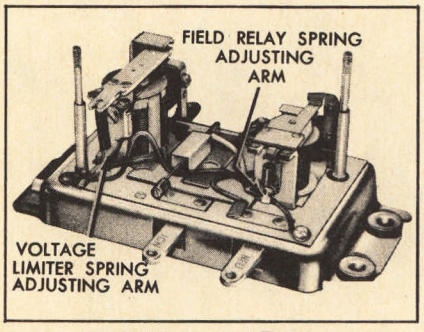
4) *Grounded stators* are tested for with the help of a *110-volt* test lamp, or an ohmmeter. Connect the test leads to the frame and to any of the stator leads. If the lamp lights, or a low ohmmeter reading is shown, the stator windings are grounded.

5) *Open stator windings* will not light the test lamp when its leads are connected to successive parts of stator leads.

6) *Shorts* in the stator are very difficult to pinpoint—even with special equipment. However, if the rotor, stator, brushes, and diodes are all OK when tested for *other* flaws, and the alternator output *still* remains low, shorted windings are the probable cause.



1. Transistorized Regulator



2. Regulator Adjustment Points

1. Terminals on most GM transistorized regulators are identical to those on conventional regulators and the various types are often used interchangeably on the same model.

2. Regulator relays with coil tension springs are sometimes adjusted by bending the hook—or spring adjusting arm—that holds the lower end of the spring in place.

3. Check diodes in transistorized regulators by unsoldering their lead wires and testing with an ohmmeter. A high resistance must be recorded in one direction, and a low resistance in the other.

4. Regulator that goes inside Delco alternator may be colored black or white, but pay attention only to the part number, not the color. Regulator at bottom has been cut away to show miniature circuitry.

5. Delcotron has not changed much over the years. Diodes are still pressed in. Note internal fan on alternator at right.

DIODE TESTS AND REPLACEMENT

The diode can be tested either with a 3-volt battery-operated test light, or an ohmmeter powered by a 1.5-volt battery *and no more*. The test lead probes are first touched to the wire and to the case of each diode in one direction, and then reversed to test it in the opposite direction. A good diode will light the lamp or produce a high ohm reading in one direction, but not in the other. If both readings are about equally high or low, or if the light will or will not light in both directions, the diode is considered to be bad.

For many years diodes were replaced by unbolting or unsoldering their leads and then using a special C-clamp tool to press them out of the alternator housings. Today, diodes cannot be replaced individually on many alternators. They are mounted in a circular plate that contains all six diodes. If one diode tests bad, you simply unbolt the plate and throw the whole thing away. In some cases, no soldering is required. If you do replace a diode or diode plate that requires soldering, there are certain precautions that you must take.

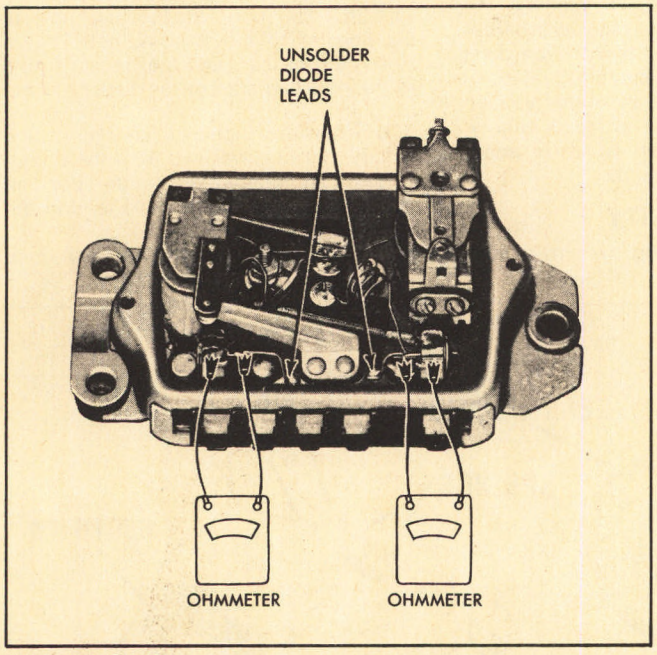
When soldering the diode's leads, a heat dam (a small metal clamp that drains off excess heat) should be attached to the wire between the solder joint and the diode itself during the soldering operation. Otherwise, you'll barbecue the diode. Delcotron positive diodes have red markings, the negative diodes are black.

REGULATOR CHECK AND REPAIRS

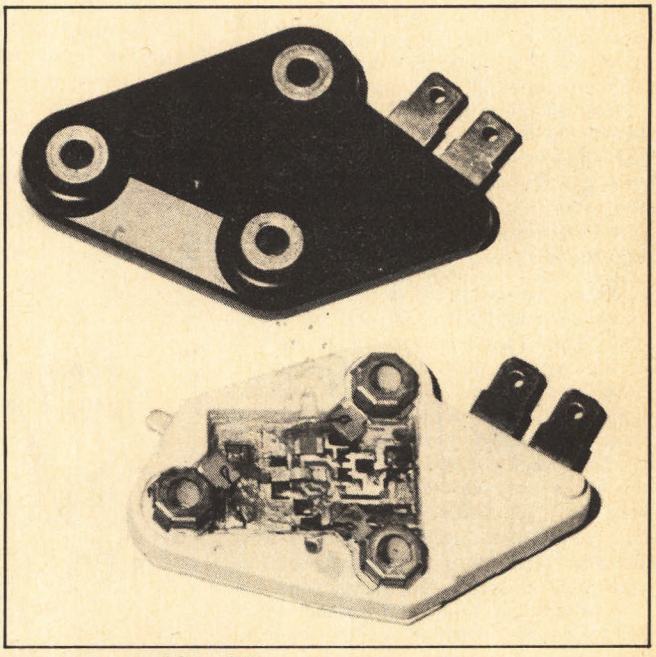
One of the first things to look for are burned-out fuse wires in Chrysler-built regulators. Two fusible wires are commonly soldered into these units to protect the system from damage due to shorts, excessive charging, and other electrical system overloads. The wires act as fuses, and whenever too much voltage passes through them, they simply overheat and melt. They are then no longer usable.

The fusible wires can be seen after removing the cover of the regulator unit. If they *have* burned out, a complete test of the regulator's operation should be made before soldering in new fusible wires and placing the regulator back in service.

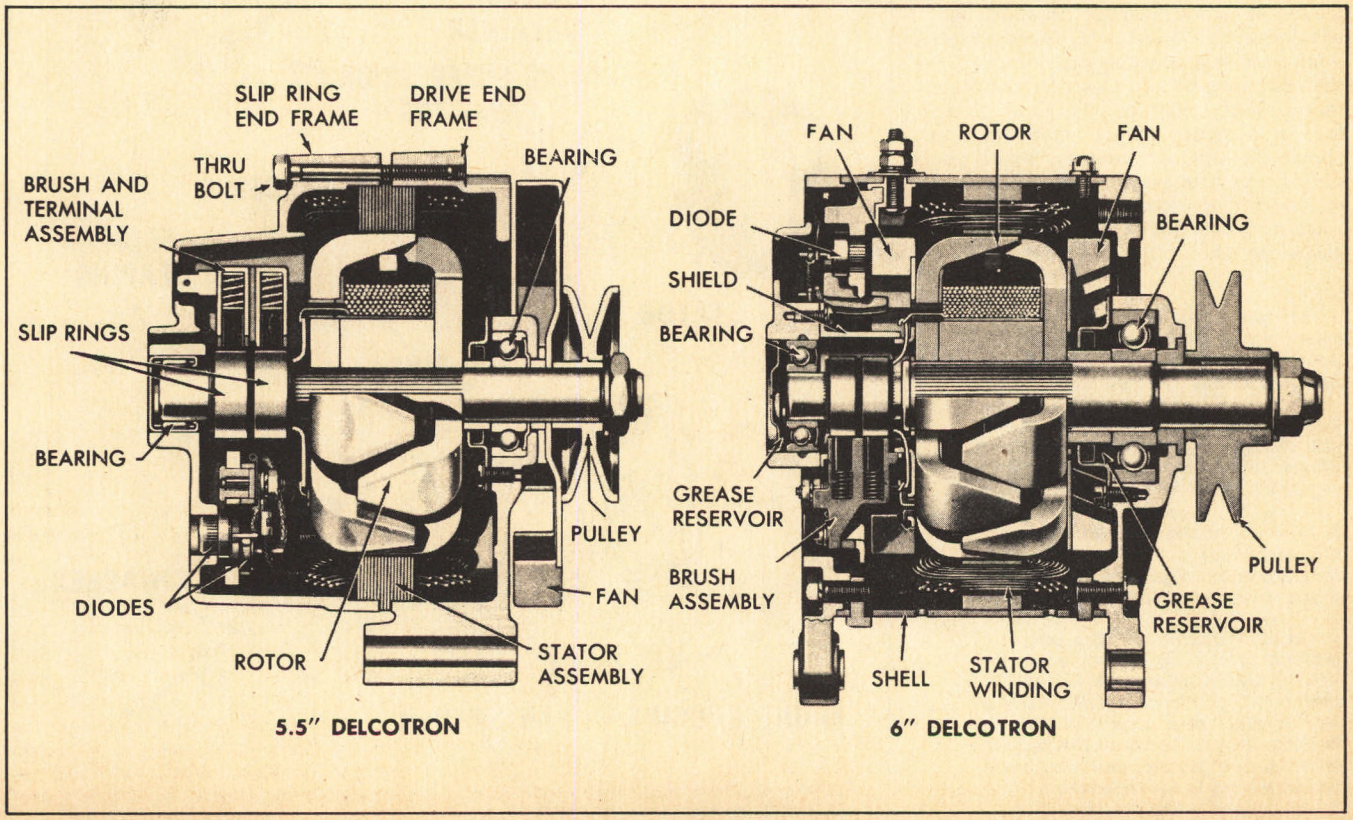
To replace the fusible wires, it is first necessary to *cut* the remains of the old ones from their terminals. You should not try to unsolder these since by doing so you may damage the fine wire coming from the relay coil. Tin the end of the new fuse wires using rosin-core solder *only*. The tinned end of the wire is then inserted into the hollow rivet at the base of the regulator so that it is against the old piece of fuse wire that was left after cutting. Apply solder to the tip of the iron until a drop falls onto the joint being formed. When both wires are soldered at their lower ends, the opposite end may



3. Testing Diodes



4. Delco Integral Regulator



5. Delcotron Alternator

be wrapped around the upper terminals and soldered—even though the original wires may only have been twisted into place.

The regulators used by Chrysler Corp. cars have just one relay unit. GM regulators have two relays and Ford even goes as high as three. Two GM-Delco types are in common use. One is a conventional load limit cutout and voltage regulating combination, and the other employs two transistors plus load and voltage relays.

The first thing to look for is dirt, corrosion residue, and burned areas on the contacts. The contacts can be cleaned with crocus cloth or a fine file. GM recommends filing with a riffler file only. Once the contacts are assured good condition, the point gaps and air gaps (the space between the relay coils and the movable point arm) should be checked and adjusted to the manufacturer's specifications.

Delco regulators have an adjusting screw to control the air gap on some units. This is a little 6-lobed knob on top of the voltage control relay. The point gaps are adjusted by bending the stationary contact mounts. On the transistorized unit the two screws holding the contact bracket are loosened and then the entire bracket moved until the correct point adjustment is attained. Single unit regulators such as those on Plymouths and other Chrysler products have their air gaps adjusted with the stationary contact bracket attaching screw fully tightened. The factory tolerance for regulator adjustments is usually around ±.002-in., which should give you a little leeway for point cleanups. Readjustment will therefore not usually be necessary unless considerable metal is removed. If the points are so badly burned that more than .004-in. must be filed from them, there's a good chance that the unit should be replaced, anyway. When you perform point cleaning and adjustment jobs with the regulator in the car, the wires connecting it to the battery should always be taken off and insulated.

1. You will rarely have to take an alternator apart this far, unless you buy a junked model for rebuilding, which may save some money.

2. Polarizing is necessary whenever you change a generator or regulator. Momentarily touch a jumper from the regulator BATT terminal to armature.

3. Wire connections on this Ford alternator look complicated, but they are easy to get back on right if you mark the wires.

4. On most alternators, the output terminal is directly connected to the battery, which means it's hot all the time. If you accidentally place a pair of pliers or a wrench so there is a connection between the output terminal and ground, you may burn up the wiring to the alternator. So be careful when working near the output terminal.

REGULATOR ADJUSTMENTS

There is no cutout or current regulator in most alternator regulators, so all you have to make adjustments on is the voltage unit. It is adjusted in much the same way as a generator voltage unit, covered earlier in this chapter. But there is one big difference. If you use a ¼-ohm resistor to simulate a fully charged battery, you must be careful to keep the engine speed down. Run the engine only fast enough to make the alternator work against the regulator. You can easily see it on your voltmeter. When the regulator starts controlling the voltage, the meter needle will hold steady somewhere between 13 and 15 volts. If you run the engine too fast, the alternator will barbecue the ¼-ohm resistor. It will even do it on a piece of test equipment. We recommend that you check alternator voltage settings against a fully charged battery, so that you don't have to worry about burning up test equipment.

POLARITY

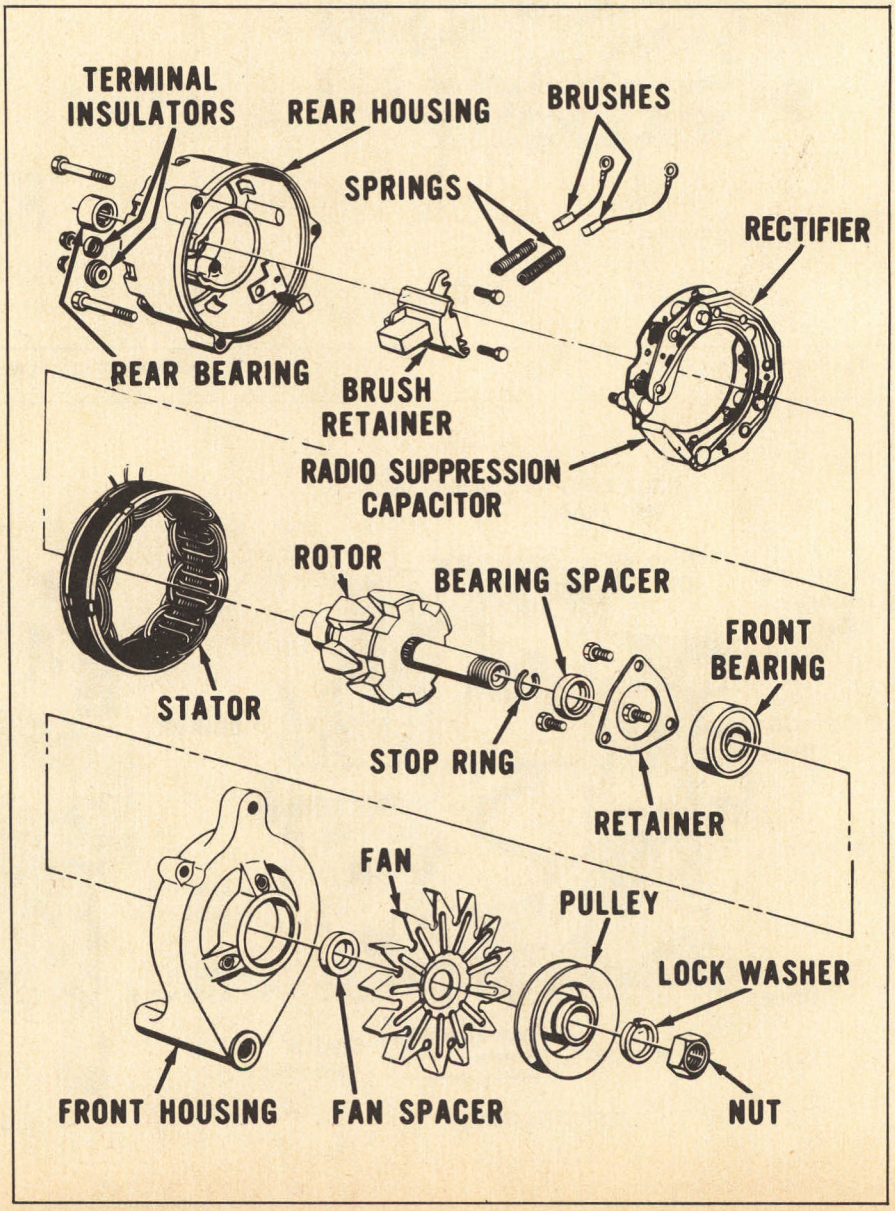
Whether the charging system in your car has an alternator or a generator, correct polarity is a very important consideration. Alternator systems can be seriously damaged by even momentary reversals of polarity, and the voltage regularity in any system is also highly vulnerable. The following precautions should always be observed when working on the charging system:

1) When putting in a battery, *always* make absolutely sure that the ground polarity of the battery, regulator, and generator or alternator is the same. Do not install regulators from negative ground systems in cars having positive ground.

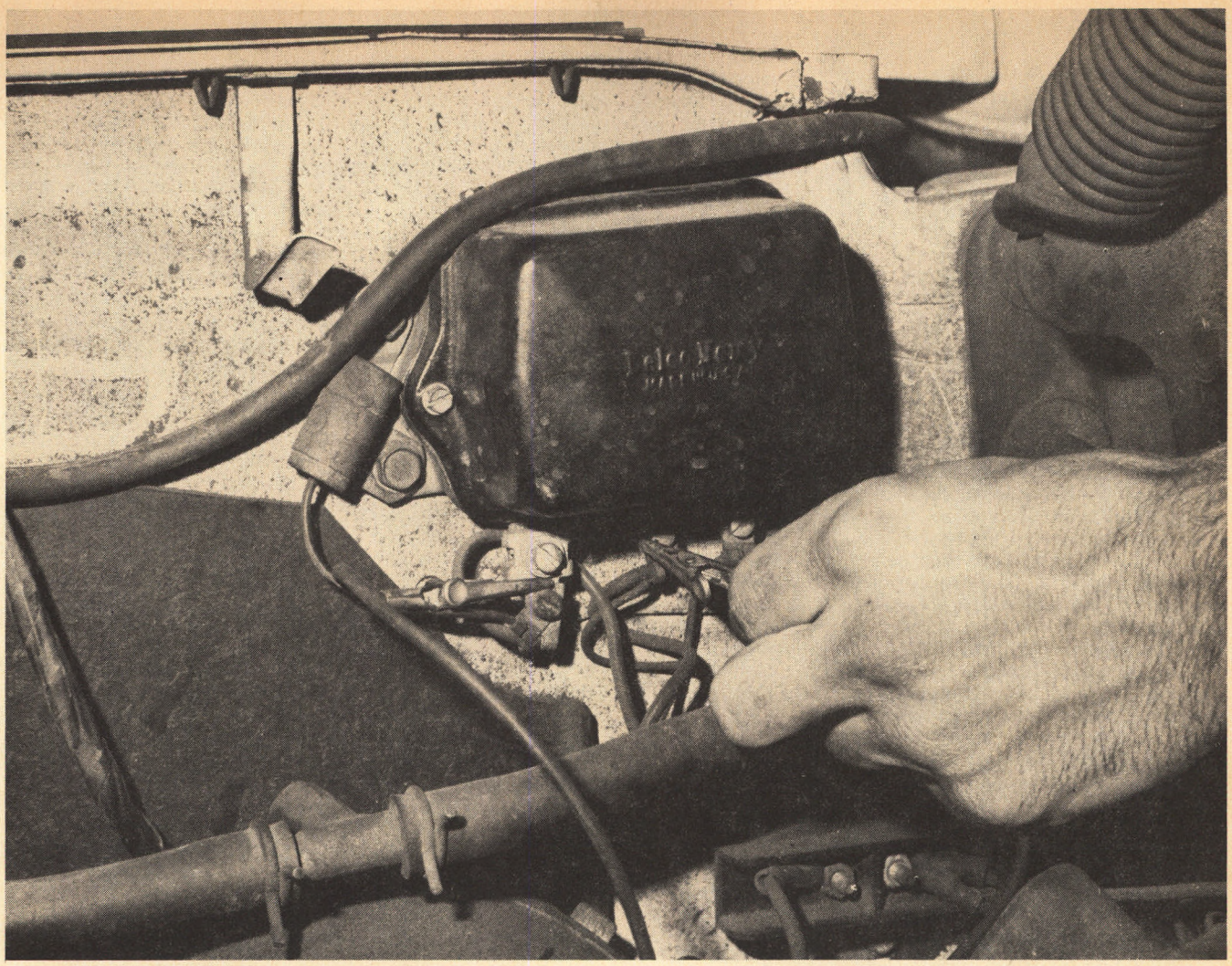
2) If you have occasion to use a booster battery and jumper cables, be sure that you hook the positive pole of the booster to the positive pole of the battery in the car, and the negative pole to the negative side of the battery in the car.

3) When connecting a charger to the battery, the positive lead from the charger must be connected to the positive battery pole and the negative lead to the negative pole.

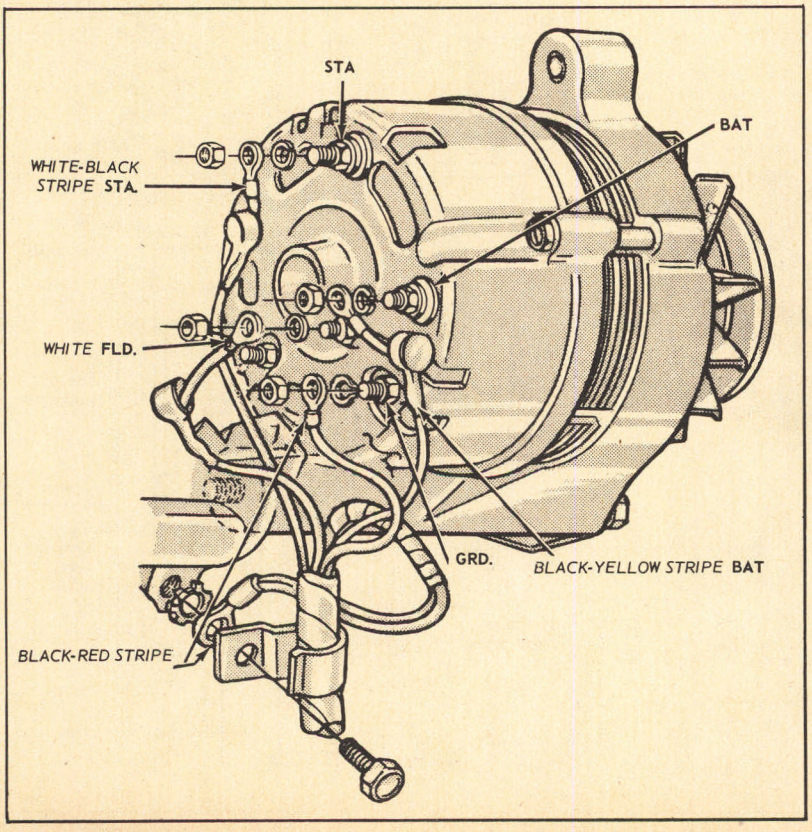
4) Never continue to drive a car when



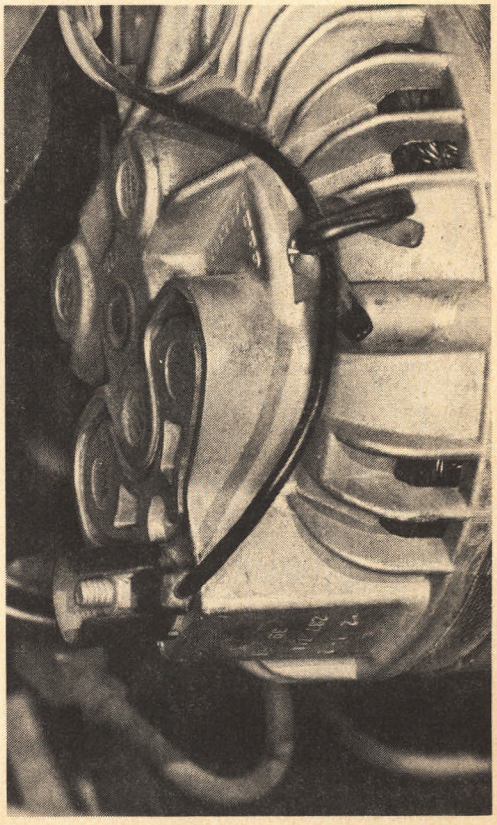
1. Ford Alternator



2. Polarizing Generator System



3. Ford Wiring Harness



4. Output Terminal

charging system trouble is evident. In the event of a loose connection that produces an open charging circuit, unregulated current of the wrong polarity may be allowed to enter the battery or alternator diodes.

5) Do not short across or ground any of the terminals on the regulator or the alternator *on alternator systems.*

When a new regulator or generator is installed, or when the old one is reinstalled after testing, the generator *must be polarized.* If this is not done, the generator—or regulator—will probably be burned out in a very short time. This is especially true on cars that have "idiot lights." An ammeter will show a no-charge more reliably following installation of an unpolarized unit. Polarizing the generator and regulator is a step that is often overlooked when making engine swaps. If you're the hot rodder type, don't bypass this vital step before "firing 'er up" for the first time, or you'll have part of the rod-building job to do over again—plus the cost of a new generator and regulator, or both.

Polarizing the generator is necessary to restore the residual magnetism to the pole shoes. A generator that sits around on the bench for a long time, or one that has been dropped during handling, may lose its residual magnetism. The momentary surge of current through the field coils that you give when you polarize the generator is enough to restore the residual magnetism. Polarization amounts to electrifying the fields with a battery. But it must be done in the right direction. The generator and all wiring should be installed and ready to operate. With the engine dead and the ignition off, connect a jumper lead to the battery terminal of the regulator and touch the other end of the lead to the regulator armature terminal for just a fraction of a second. It only takes just a touch and the job is done.

Polarization is not necessary on an alternator because it does not have a cut-out. The alternator gets field current whenever the ignition switch is on, so there is no need to polarize it or make any jumper connections when installing a new alternator.

BEARINGS

Generator and alternator bearings have a particular notoriety for "going out" at the worst possible times. Even if they don't seize up half-way between service areas on the New York Thruway, they can still start making more noise than a worn-out cement mixer filled with empty beer cans—usually when you've just driven off on your first date with the prettiest girl in the whole world.

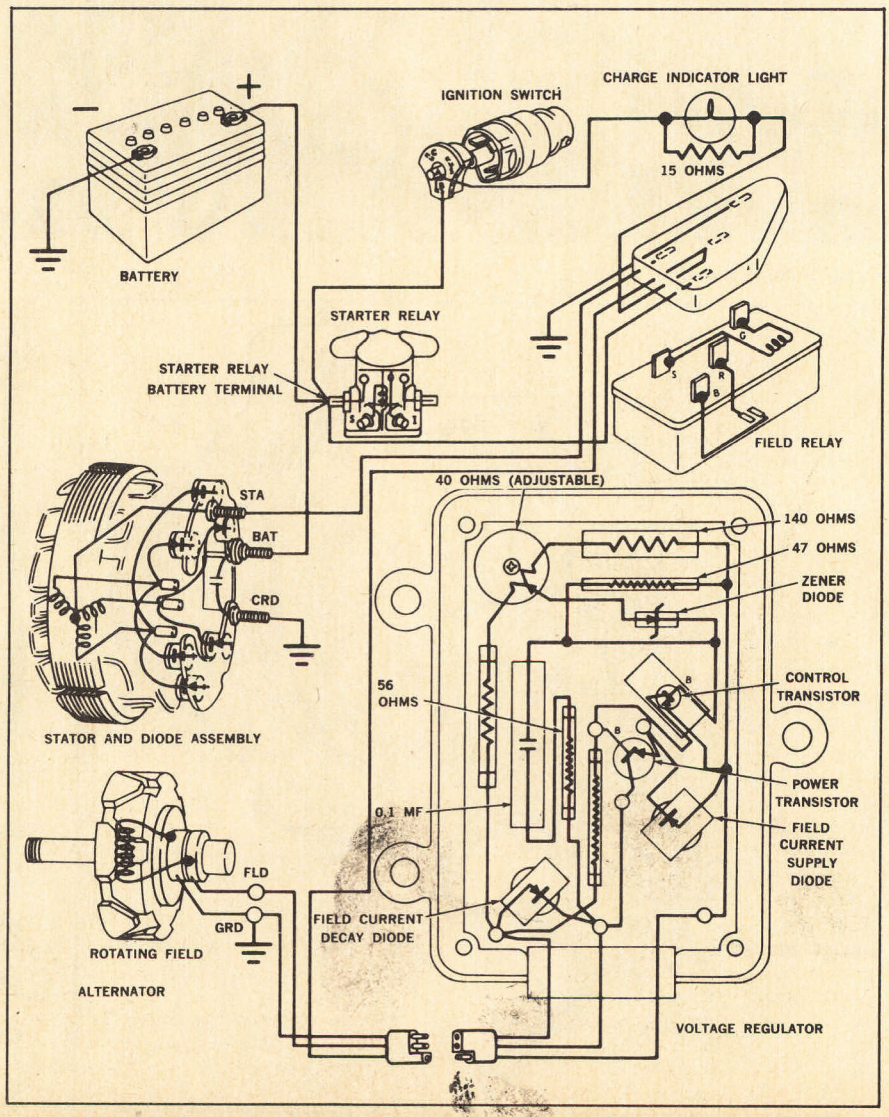
Most generators have one or two oil holes that are meant to be given a tall drink of engine oil when the car is greased. Unfortunately, these are frequently overlooked by filling station attendants, since some cars have them and others do not. The generator must be lubed according to schedule.

Most alternators, and an increasing number of generators, have "oil-less" bearings—which is to say, they have been prelubricated at the factory or are only packed upon installation. On the majority of alternators, the bearings must be replaced if they have lost their lubrication. Delcotron 6-in. and 6.2-in. units can have their bearings removed and relubricated with Delco No. 1948791 grease or its equivalent. The 5.5-in. Delcotron has ball bearings only at the drive end so that is the only end that can be repacked.

If bearings have gone bad in an alternator or generator you will, of course, need to replace them.

The bearings can be driven out of the end plates using short sections of pipe that have approximately the same diameter as the inner and outer ball bearing races. On most units, the brush-end bearing has a stamped metal grease retaining cap over its outer end. The bearing is driven from the "inside" so that this cap is forced out by the old bearing. A new cap is sometimes a part of the replacement kit. Check before destroying old one.

The drive-end bearing can be removed only after the V-belt pulley has been tak-



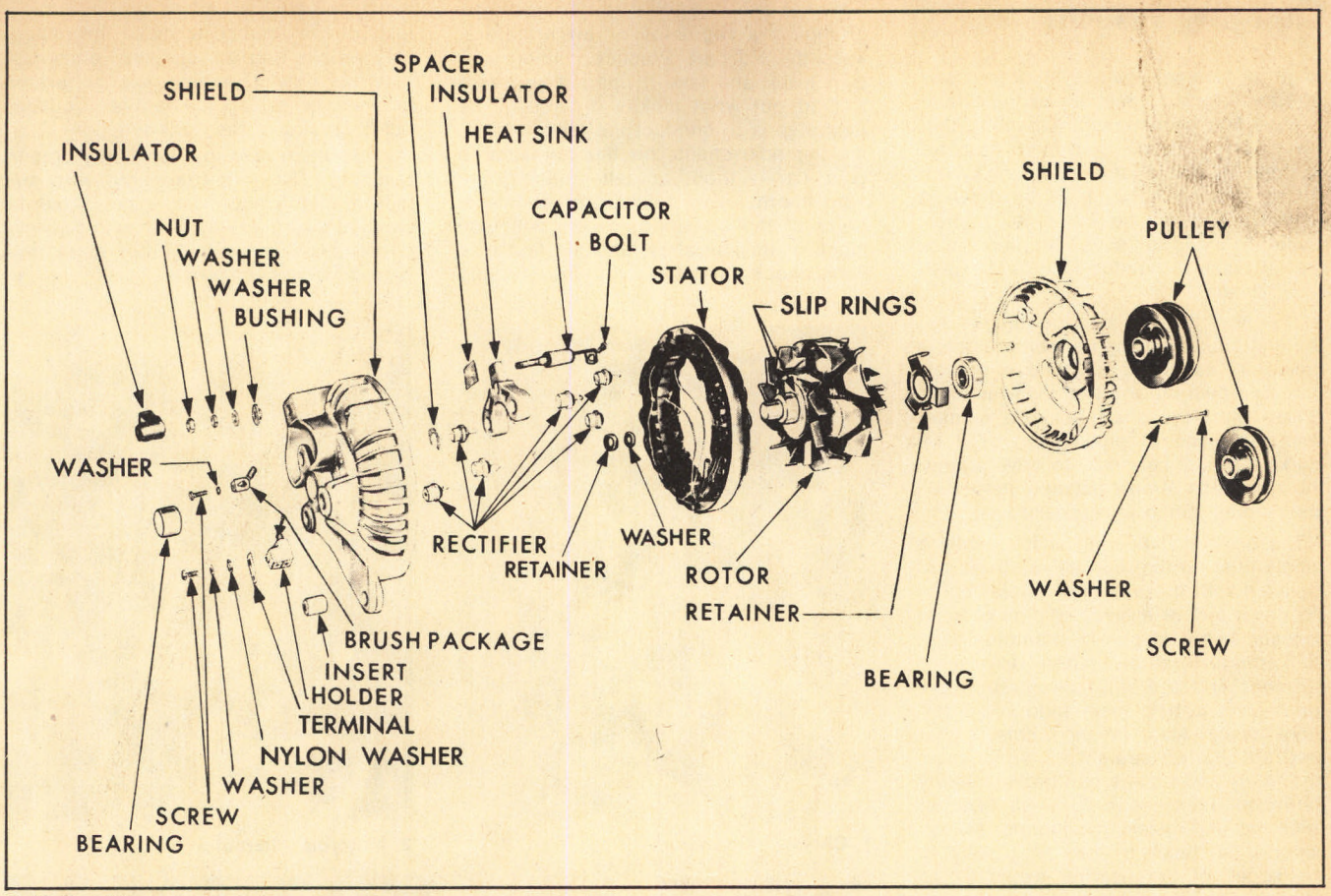
1. Alternator and Transistorized Regulator

1. Wiring diagram with Ford alternator and transistorized regulator. Modern charging circuits like this require very little maintenance.

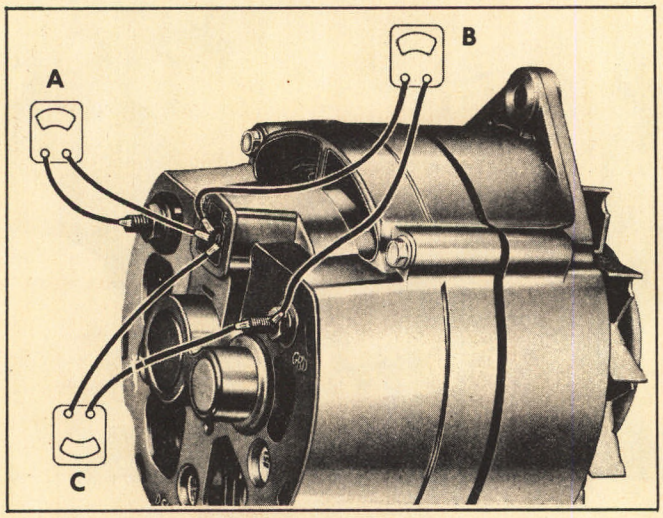
2. MoPar alternator is of same basic design as Ford alternator, except that until 1972 the rectifiers (diodes) mounted directly into the stator rather than a separate subframe, and could be replaced individually. From 1972 on, rectifiers are mounted in negative and positive heat sink units and entire assembly must be changed if one or more rectifiers are bad.

3. Ohmmeter hook-ups used to test diodes and field current. Test A: This is a check of the positive diodes. Note reading and reverse test leads. The meter should record a high reading in one direction and a low reading in the other. Test B: Perform same test as A. Similar readings in both directions mean faulty negative diodes. Test C: Meter should read a maximum of 7-10 ohms. Low reading means bad brushes.

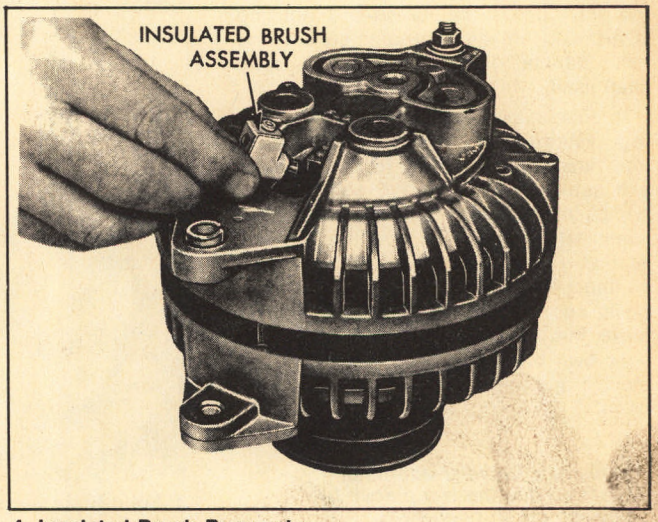
4. The insulated brush can be removed separately from Chrysler Corp. alternators. Notice also the three diodes in their external heat sink adjacent to the terminal in the rear.



2. MoPar Alternator



3. Delcotron Diode and Field Test



4. Insulated Brush Removal

en off the shaft. On Chrysler alternators this requires some special tools, since the pulley is an interference fit with the rotor shaft. In view of the fact that the tools cost more than having the bearing replaced in a shop, it's probably best to farm out the entire job. On other generators and alternators a nut is removed from the center of the pulley and the pulley slipped off the shaft. On Ford alternators a gear puller can be used without damaging the pulley. Delcotron alternators have a particularly nice feature for pulley removal. The end of the rotor shaft has a recess that will accept a 5/16-in. Allen wrench. The Allen wrench allows you to keep the rotor shaft from turning while undoing the 15/16-in. nut with a box wrench. When reinstalling the pulley nuts, a torque of approximately 50 ft.-lbs. is adequate.

Pulleys themselves frequently go bad—especially on generators that have stamped metal pulleys made up of two spot-welded halves. The reason for their failure is not that the pulleys are of inferior quality, but that fan belts are often overtightened. A fan belt that does not have the correct degree of deflection, as it is specified in the car owner's manual, puts an extremely heavy strain on the generator pulley as well as on the generator and water pump bearings. The pulley, being weakest, is usually the first part to fail, but if the car's owner has been careless about oiling the generator bearings, they are also quite likely to burn out.

When tensioning the fan belt, use only a soft piece of wood to exert pressure against the side of the generator. On V-8's with high-mounted alternators or generators it is usually possible to tension the belt correctly with only hand pressure. Incidentally, *never* pry against the side of an anti-smog pump to adjust belt tension. The housings are very thin and can be easily bent, which will interfere with the action of the air pump's rotor.

Once the pulley is off the shaft, the bearing can be driven out along with the rotor or armature by suitably supporting the end plate and tapping on a short

length of pipe set against the *outer* bearing race. In some cases a bearing retainer must first be removed. Assuming that the bearing is no good, it can be clamped in a vise and the shaft driven out by placing a block of hard wood against it and striking it with a hammer. If you are trying to "save" the bearing, a special puller is needed in order to prevent damage.

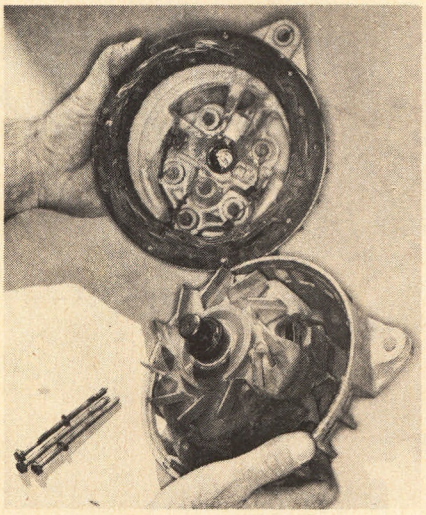
The new bearing can be driven into the end housing using the same piece of pipe that was used to remove the old one. The bearing and end plate are then driven onto the shaft using a smaller diameter piece of pipe (⅞-in. or 1 in. works for most bearings) to drive against the *inner* race. Amply detailed instruction sheets often come with rebuild kits.

The brush-end bearing is frequently a simple bushing that can be removed and replaced with the use of a regular bushing driver tool or a piece of pipe or steel rod somewhat larger in diameter than the armature shaft. When driving in bushings and bearings, always lubricate the outside to help them slide into place more easily. Also, be very careful that they are started straight to avoid damage. Alloy end frames can be very easily deformed if excessive force is used in removing and installing bearings. Always support the bearing area as closely to the edges of the bearing assembly as possible to prevent this. Chrysler alternators should have the pulley pressed onto the shaft before the brush-end housing is installed on the alternator so that the force can be directed against the rotor shaft itself.

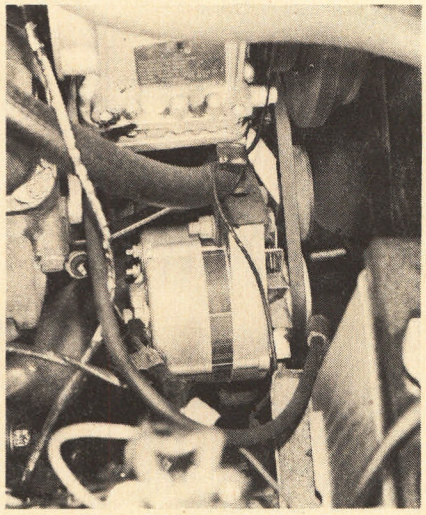
In conclusion, let it be said that charging systems, like many of the electromechanical components found on modern automobiles, *do* have some rather complicated aspects. But they also have some extremely simple qualities as well. At first you may feel yourself incapable of handling some of the electrical diagnosis and adjustment, and may wish to leave this to an "expert" while limiting your own part of the repair work to removing and installing the related components.

However, if your repairs include changing a regulator or an armature, keep the old part. Practice making your own tests, and take it apart if you wish to find out what makes it "tick." The next step is to conduct the tests used in making adjustments on the regulator in your car—without actually making the adjustments. Eventually, the electrical parts of the charging system will lose much of their mystery, and the first time your checkup actually finds something wrong, nine times out of ten you'll have lost your reluctance to make the necessary repairs and adjustments yourself. It may be only changing the generator brushes, or setting the regulator cutout, but it's a step in the right direction.

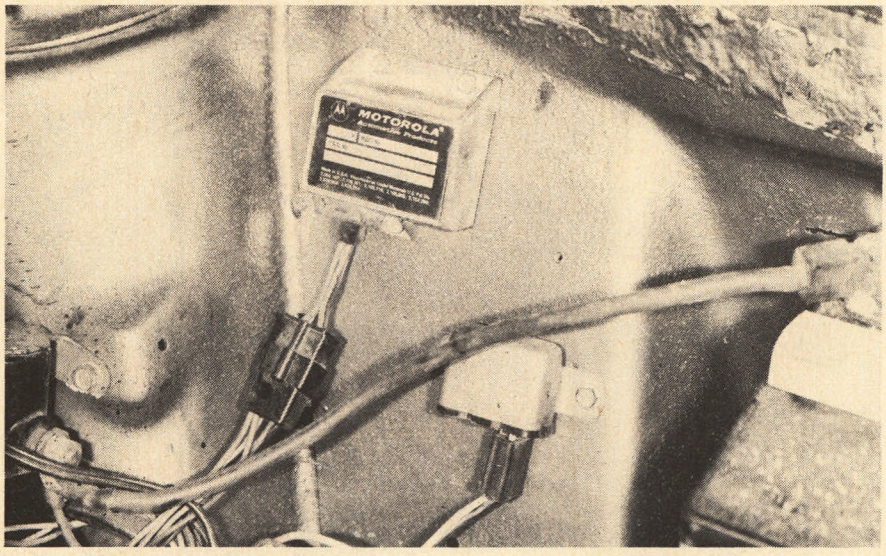
It has been said that familiarity breeds contempt. The old graybeard who authored that famous cliche neglected to mention that it is only fools who become contemptuous—on the other hand, the wise develop confidence.



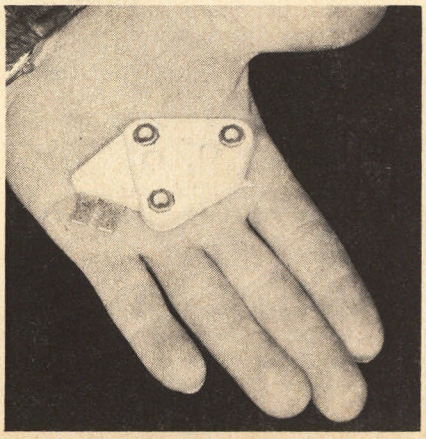
1. Chrysler Alternator



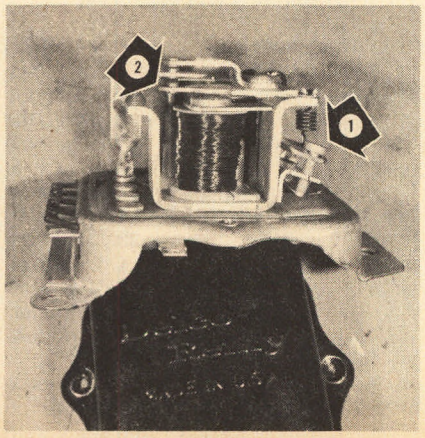
2. Motorola Alternator



3. Solid-State Regulator



4. Delcotron Regulator



5. Voltage Regulator Adjustment

1. This is a Chrysler alternator separated into the two pieces by removing the through-bolts.

2. Low-mounted alternators like this Motorola are difficult to reach for belt tightening. When you remove this unit, take it out from the bottom.

3. Motorola solid-state regulator is a nonadjustable plug-in unit on the fenderwell—if it malfunctions, you have to replace it with a new one.

4. This is the solid-state diode rectified voltage regulator unit incorporated as an integral part of all 1973 Delcotron alternators. It's a replace-only unit if it goes bad.

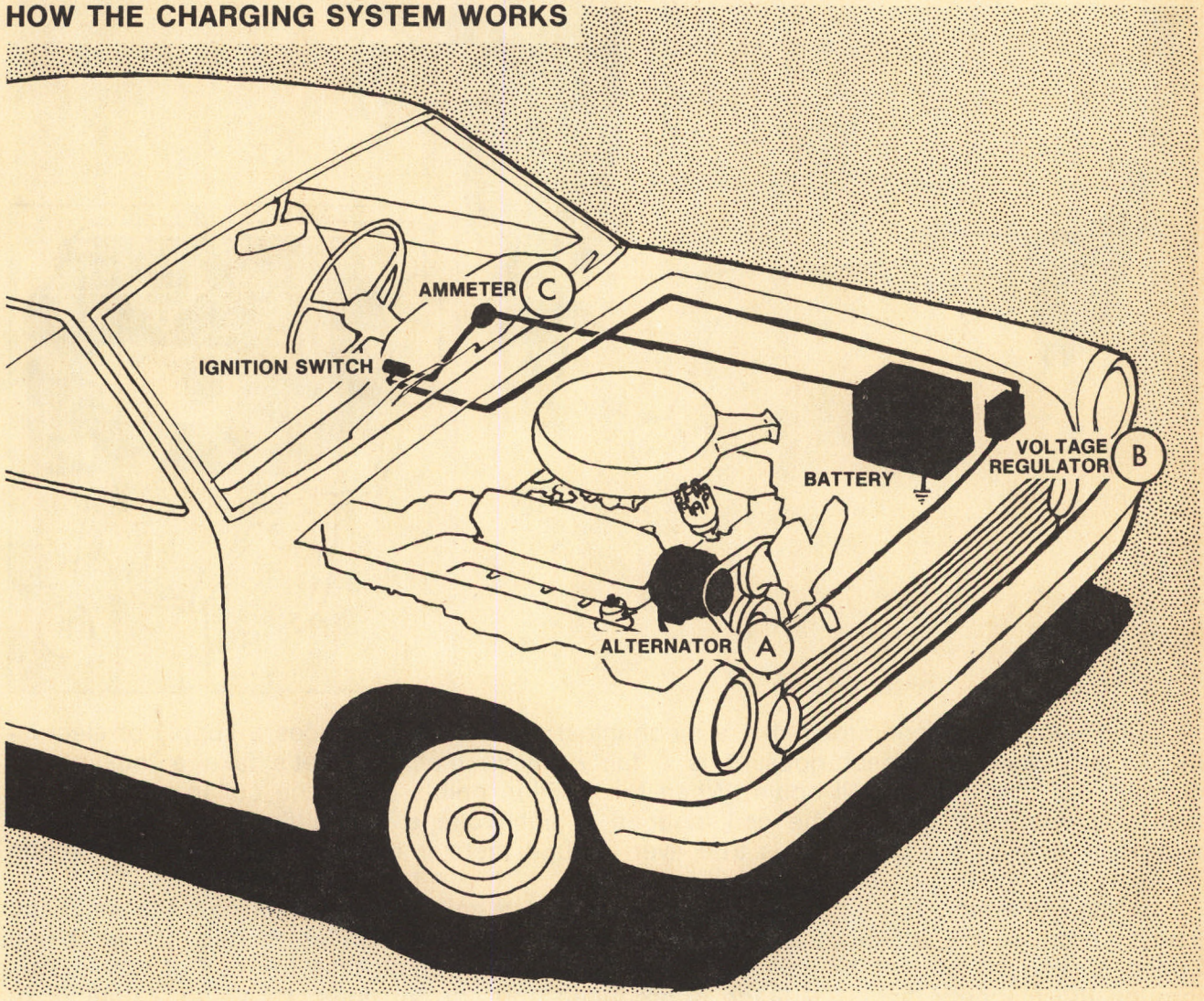
5. Voltage regulator adjustment is made with screw (1). Incorrect adjustment on this unit caused the lower points (2) to arc continuously, burn out, and ruin regulator assembly.

TROUBLESHOOTING THE CHARGING SYSTEM

As you have seen in the chapters on the starter and ignition systems, the battery is the heart of the electrical network of any automobile. This chapter deals with the mechanical/electrical means by which the battery is kept in a state of charge while the engine is running.

The charging system actually does more than charge the battery. It supplies the electricity for running the ignition system and all the electrical accessories. Besides the battery, the charging system consists of the generator or alternator, the regulator, the ammeter or a warning light on the dashboard and the wiring between these parts.

HOW THE CHARGING SYSTEM WORKS

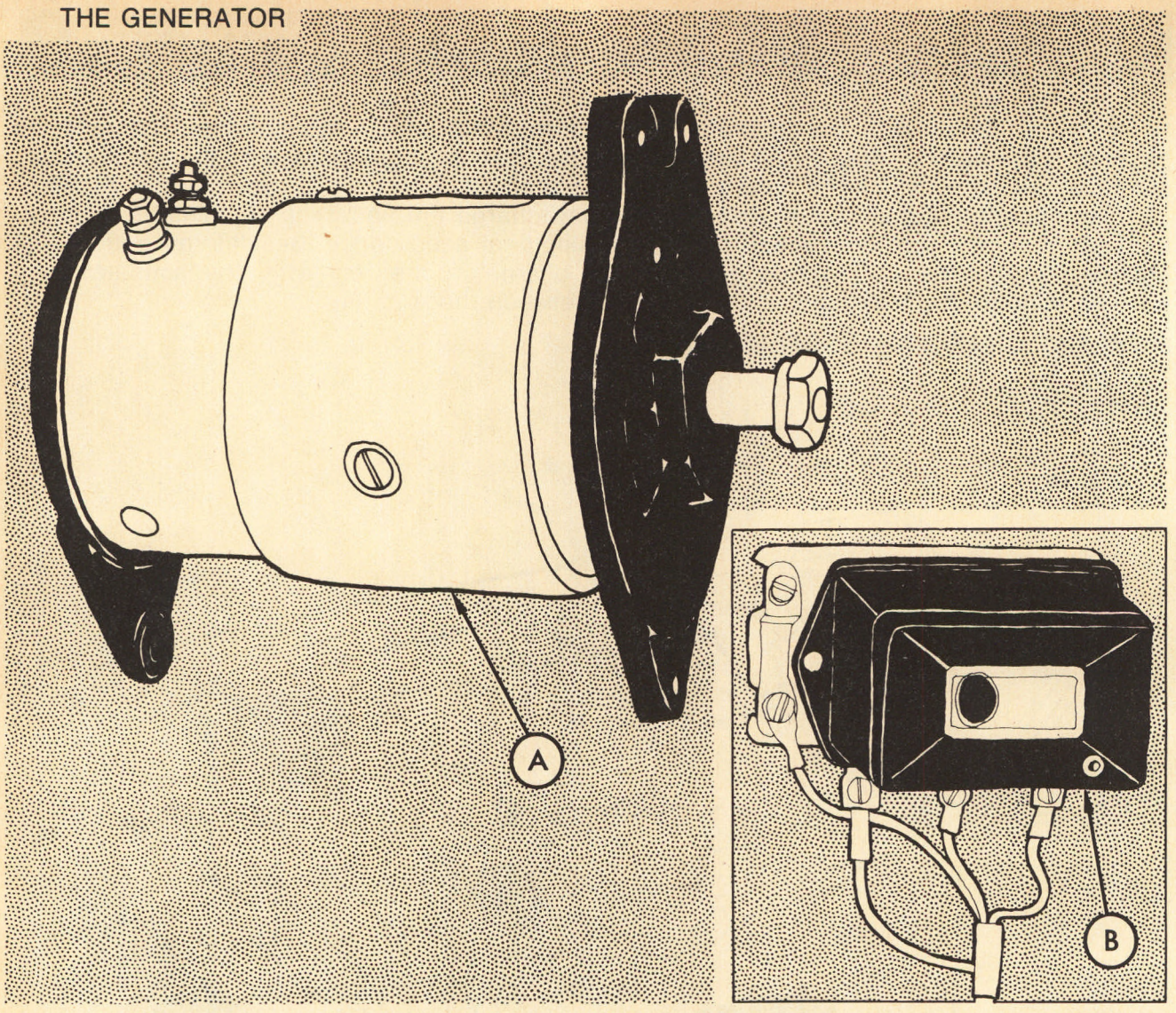


The charging unit, either a generator or alternator (A), is operated by a belt running from the pulley on the engine crankshaft. When the engine is running, the rotation of the crankshaft turns the charging unit at a speed high enough to produce sufficient electrical energy to charge the battery and run all other electrical parts.

NOTE: NOT ALL CHARGING SYSTEMS ARE COMPLETELY EFFICIENT AT LOW ENGINE SPEEDS. IDLING MAY CAUSE REDUCED OUTPUT.

As engine speed varies, the output of the charging unit varies. The regulator (B) is a device which controls two major functions. First, it controls the amount of current being returned to the battery to charge it. Second, it controls the voltage output of the charging unit to prevent damage to the system. The ammeter (C) or warning light, a meter that measures amps (units of charging current), is mounted inside the car where it is visible to the driver.

THE GENERATOR



The automotive generator (A) is a mechanical device that produces a supply of electricity. As electrical equipment goes, it is a fairly simple machine. Let's take a look at the operation of the ignition coil again. When the ignition points open, the collapsing magnetic field in the primary side of the coil induces a high voltage and a flow of current in the secondary side of the coil. This is true even though there is no direct electrical connection between the two. The process is called induction.

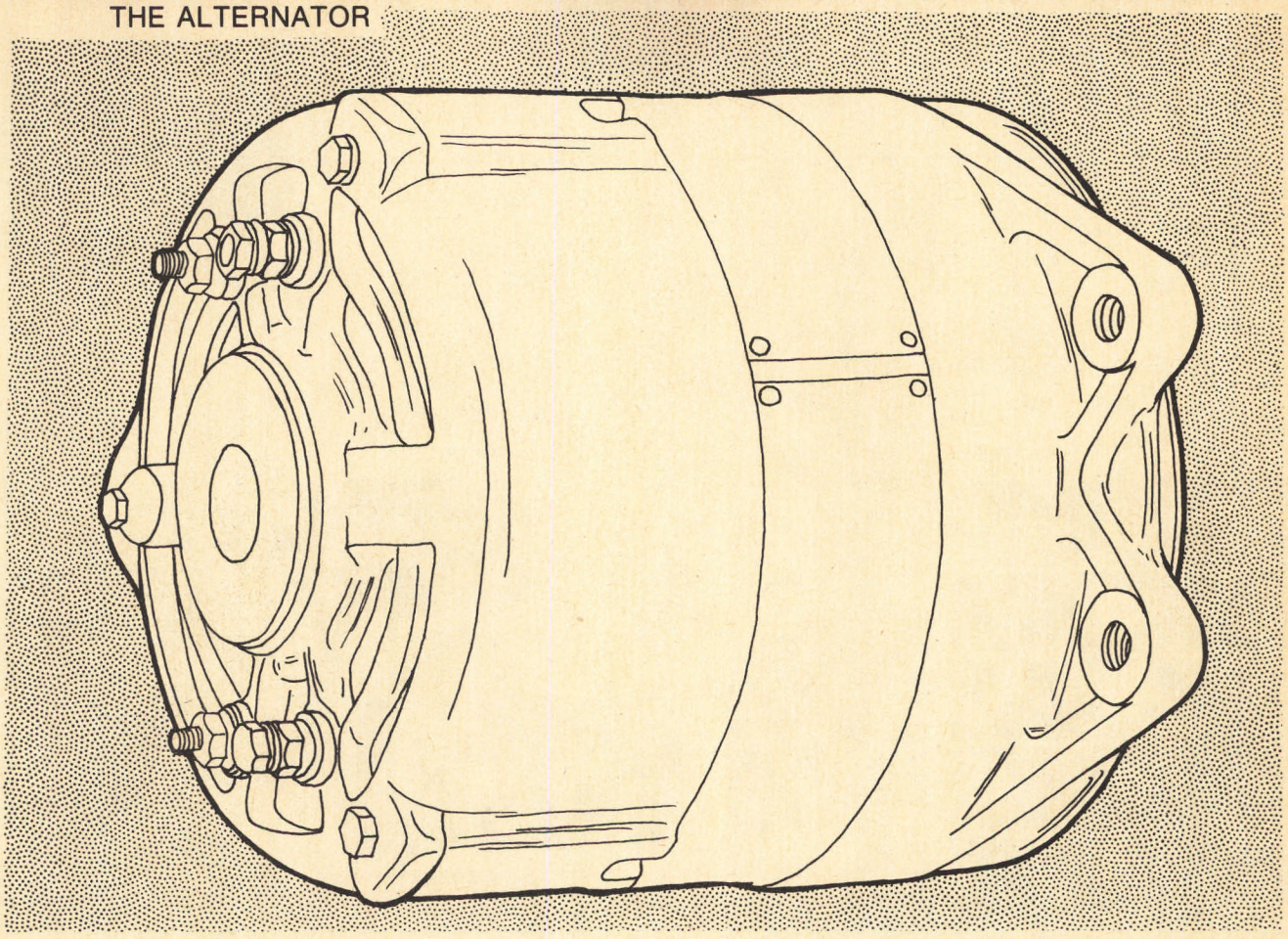
In the generator, this process takes the form of a coil which rotates past the magnetic field to produce the effect of a rising and falling magnetic field, as though it were being turned on and off like the primary side of an ignition coil. Each time the coil of wire moves through the magnetic field, a voltage is produced and current flows. By using a number of magnetic fields and a number of loops of wire, it is possible to produce the amount of electric voltage and current needed to charge the battery and power the electrical equipment of the automobile.

The rotating coils of wire inside the generator are called the armature. Along with some small magnets to provide the initial magnetic field, there are electromagnetic coils attached to the case of the generator. These are known as field coils. Once the generator is in motion, part of the electricity developed is fed back to the field coils to increase the magnetic fields, thereby increasing the output of the generator.

If there were no controlling force, the generator would produce a higher and higher voltage as engine speed increased. The voltage regulator is designed to prevent this. The voltage regulator (B) controls the electricity fed back to the field coils and keeps the output of the generator constant over a wide range of engine speeds. The voltage regulator also has two other functions. First, it controls the amount of current directed to the battery to prevent overcharging the battery, and second, it cuts off the circuit when the engine is not running. In generator systems, the voltage regulator is a separate unit.

TROUBLESHOOTING THE CHARGING SYSTEM

THE ALTERNATOR



After the kind of generator just described had been in use for many years, another form of generator was designed. It's called an alternator. This unit, used in most modern automobiles, is much more efficient. It is generally lighter and smaller than a generator but capable of delivering the same amount of power.

The alternator works on the same physical principles as the generator, but the mechanical arrangement is different. Instead of fixed magnetic fields and rotating armature coils, the alternator used fixed coils inside the case, and the magnetic field is produced in the rotating shaft at the center of the alternator.

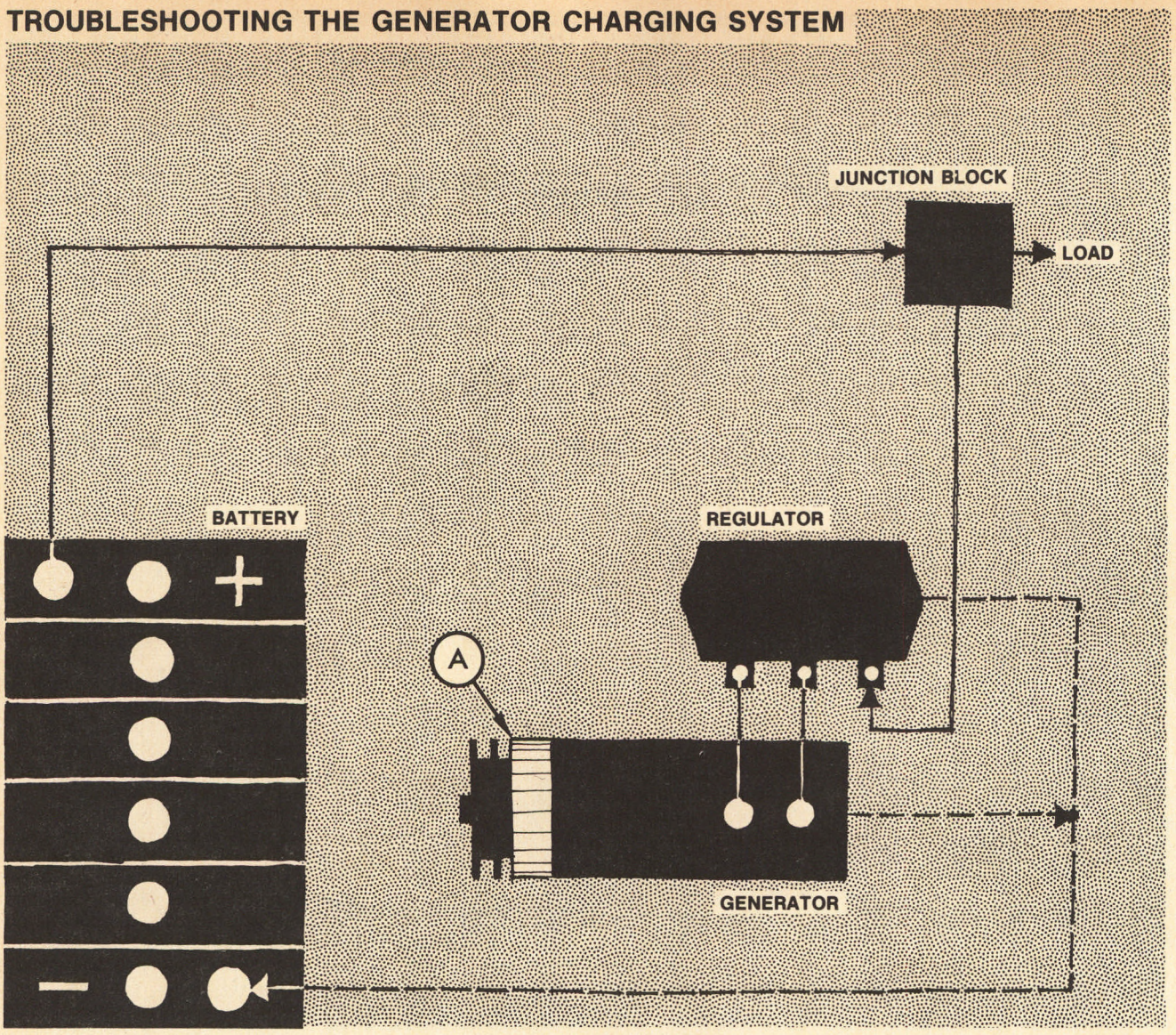
In both the generator and the alternator, the movement of the coils relative to the magnetic field (it makes no difference which actually moves as long as there is a movement of one relative to the other) produces a voltage which rises and falls. As it rises and falls, the polarity of the voltage changes. This produces an alternating (AC) current (one that reverses direction) exactly like that used in house lighting and appliances. This current cannot be used by the battery or other automobile equipment, as they all work on direct current (DC).

In the generator, this difference in currents is taken care of by the way the electricity is picked off the armature. The contacts in the generator are called brushes. They ride on a rotating contact on the end of the armature called the commutator. The commutator is divided into segments so that at any one time, the brushes are only in contact with the output of one coil. This arrangement allows current to be drawn in only one direction, converting the AC output to a DC output.

In the alternator, since the coils which produce the electrical current are fixed and do not rotate, some other method had to be found to convert the AC output to DC. It was accomplished by a solid-state device called a rectifier. In early alternators, this was a separate piece of equipment, but in later models, it is physically part of the alternator unit.

The voltage regulation of the alternator is handled by a separate regulator, but unlike the regulator of the DC generator, the one for the alternator is often a solid-state (transistorized) unit.

TROUBLESHOOTING THE GENERATOR CHARGING SYSTEM



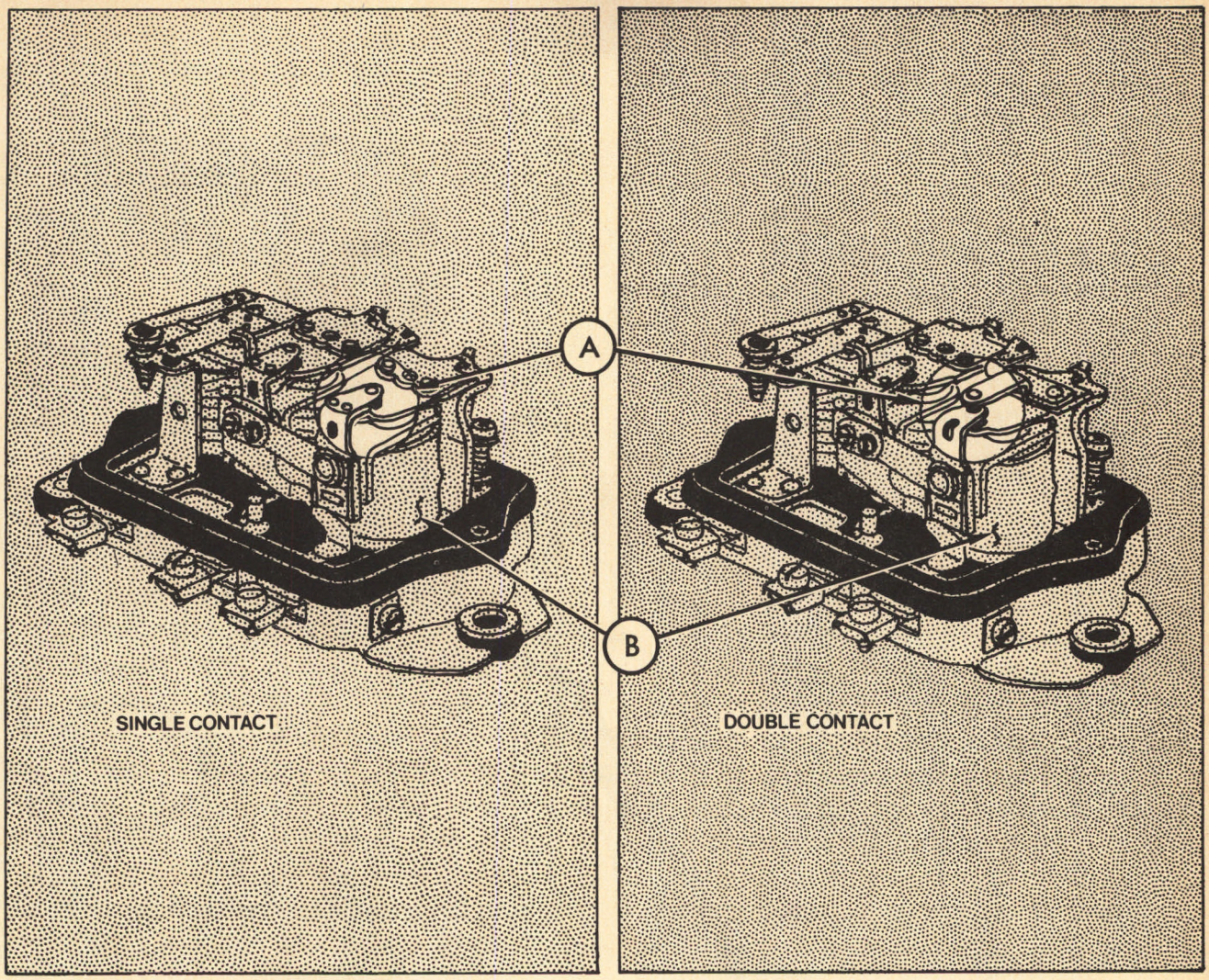
Even without any test equipment you can often locate troubles in the charging system of your automobile. Remember, *check the obvious first!* Symptoms of charging system trouble are: hard starting (check starting system also) and a low ammeter reading or warning light that comes on or stays on at all times. Also, a battery that frequently requires charging is a good sign of a charging system malfunction, but the battery itself should always be checked first. If instrument lights burn out frequently, it can mean that the voltage is too high. Headlights that brighten and dim as engine speed varies are a sign of charging system problems too.

One of the most common problems in the charging system is a drive belt that is too loose. These belts stretch with use and can become loose enough to slip, allowing the generator to slow down past the point where it can deliver the required amount of current to the system. Look for shiny or glazed sides on the belt where it comes in contact with the sides of the pulleys. The generator is mounted in such a manner that it can be adjusted to increase or decrease the tension on the belt. The shop manual will give the required tension. Don't tighten the belt too much. This can cause generator bearing failure by imposing too heavy a side load on the armature shaft. If the belt appears to be torn or cracked, replace it. If it has been slipping and the surfaces have been glazed by heat, consider changing it. The price is low, and a glazed belt is sure to fail at some later time.

Check all wiring connections, starting with the battery cables. Look for corrosion, loose connections and frayed or broken wires between the battery, generator and voltage regulator. If the car will run, start it and listen to the generator for possible noisy, dry bearings or the sound of something rubbing, such as the cooling fan blades (A) on the front of the generator.

If everything appears okay, you can then eliminate the battery as a source of trouble by performing the cranking voltage check as outlined in the chapter on starting systems.

TROUBLESHOOTING THE CHARGING SYSTEM



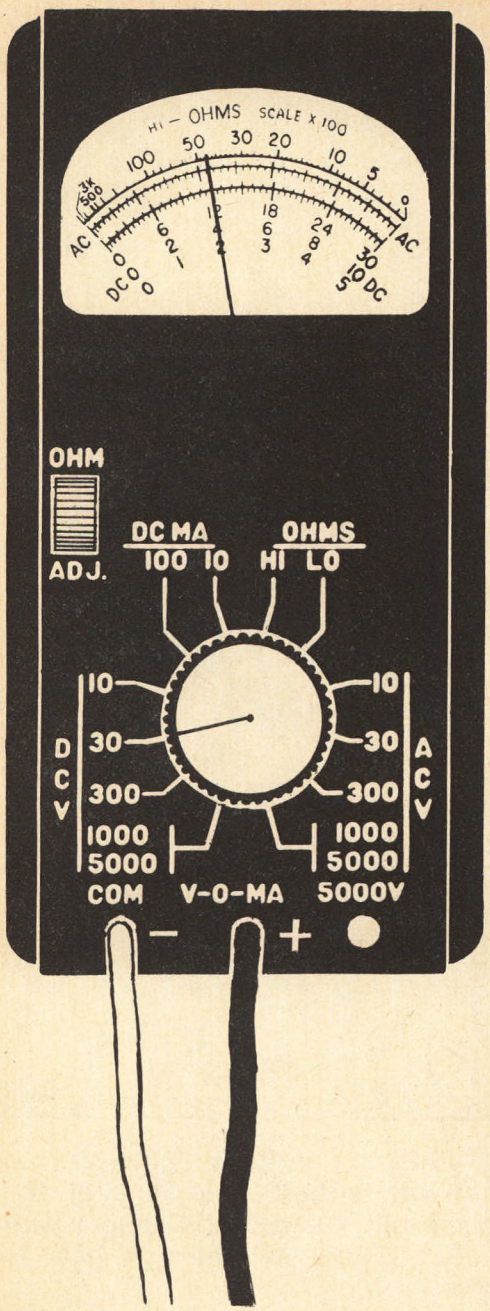
A quick check of the generator charging system is possible, using a multimeter to measure the output of the generator. By connecting a jumper wire to the FLD terminal on the voltage regulator (see the test opposite), then connecting the other end of the jumper wire to ground, the voltage to the field coils in the generator is cut off. This step makes it easy to determine if the problem is in the regulator or in the generator itself.

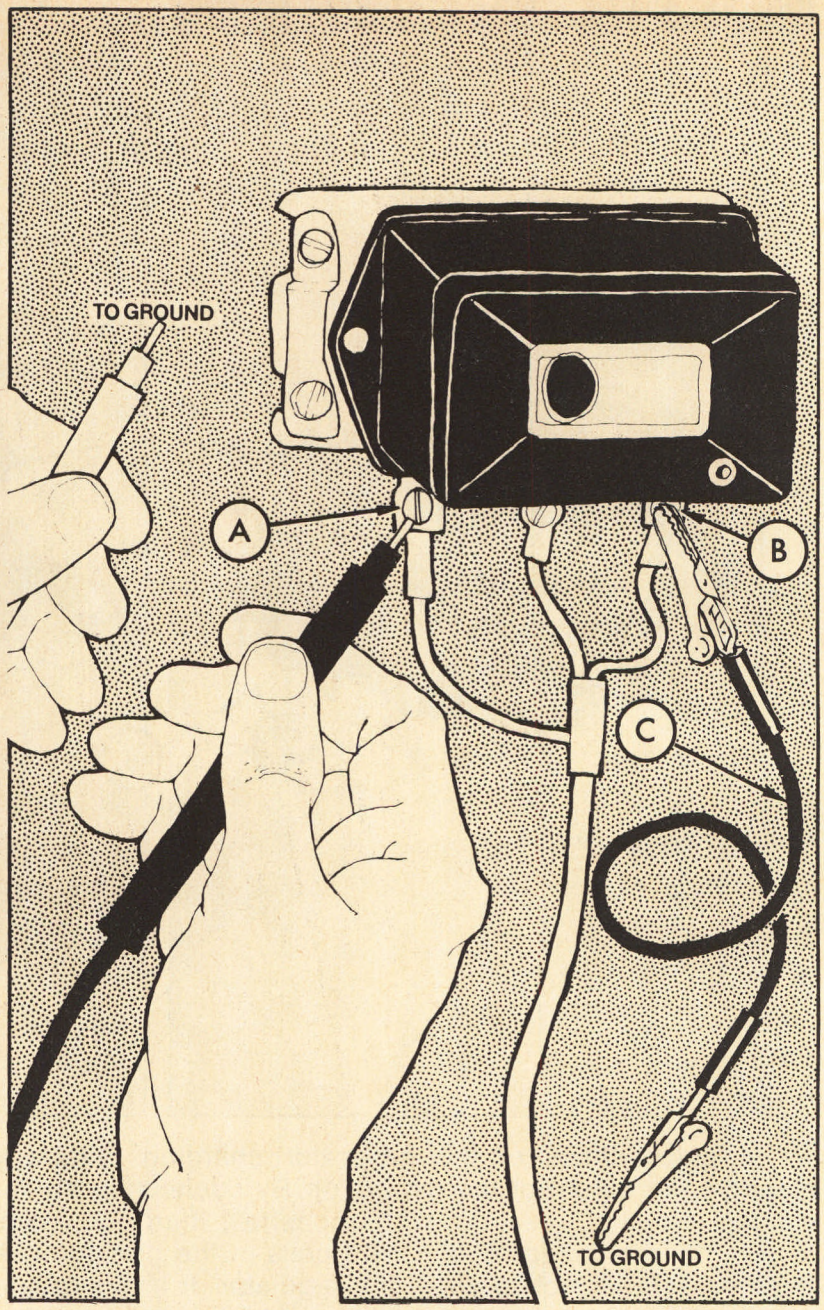
There are two different voltage regulator designs. These are called "A" circuit regulators and "B" circuit regulators. Most General Motors cars (Chevrolet, Buick, etc.) have the A circuit. Ford cars usually have the B circuit regulator.

Both kinds of regulators are available in two styles, a single-contact model and a double-contact model. The double-contact voltage regulator is usually associated with a heavy-duty generator system, but it is becoming more common on standard automobiles, especially those with accessory equipment such as air conditioners or power seats and windows. This gives the troubleshooter a total of four different types of regulator that he may have to check. If you are uncertain which type your car has, check the outside cover. Many regulators are so marked on the outside. If the voltage regulator is unmarked, refer to the shop manual for your car or remove the cover and examine the voltage limiter relay (B). The voltage limiter relay is usually on one end of the regulator rather than being in the middle. Examine the contacts (A). If there is more than one set of contacts on the voltage relay, it is a double model.

CAUTION: REMOVE THE GROUND (-) CABLE FROM THE BATTERY BEFORE REMOVING THE REGULATOR COVER TO AVOID ELECTRICAL SHOCK OR DAMAGE TO THE REGULATOR.

TESTING THE "A" CIRCUIT SINGLE-CONTACT SYSTEM





Using the multimeter, check the battery with the engine off. Connect the positive lead (+) of the multimeter to the positive post of the battery. Connect the negative lead (-) of the multimeter to the negative post. Measure the battery voltage. The voltage should be between 11.5 and 12.5 volts (for a 12-volt battery).

Connect the positive lead of the multimeter to the BAT terminal (A) of the regulator. Attach the negative lead to a good ground on the engine, and connect a jumper wire (C) from the FLD terminal (B) to ground. Set the meter selector switch to read in the 15- to 20-volt range.

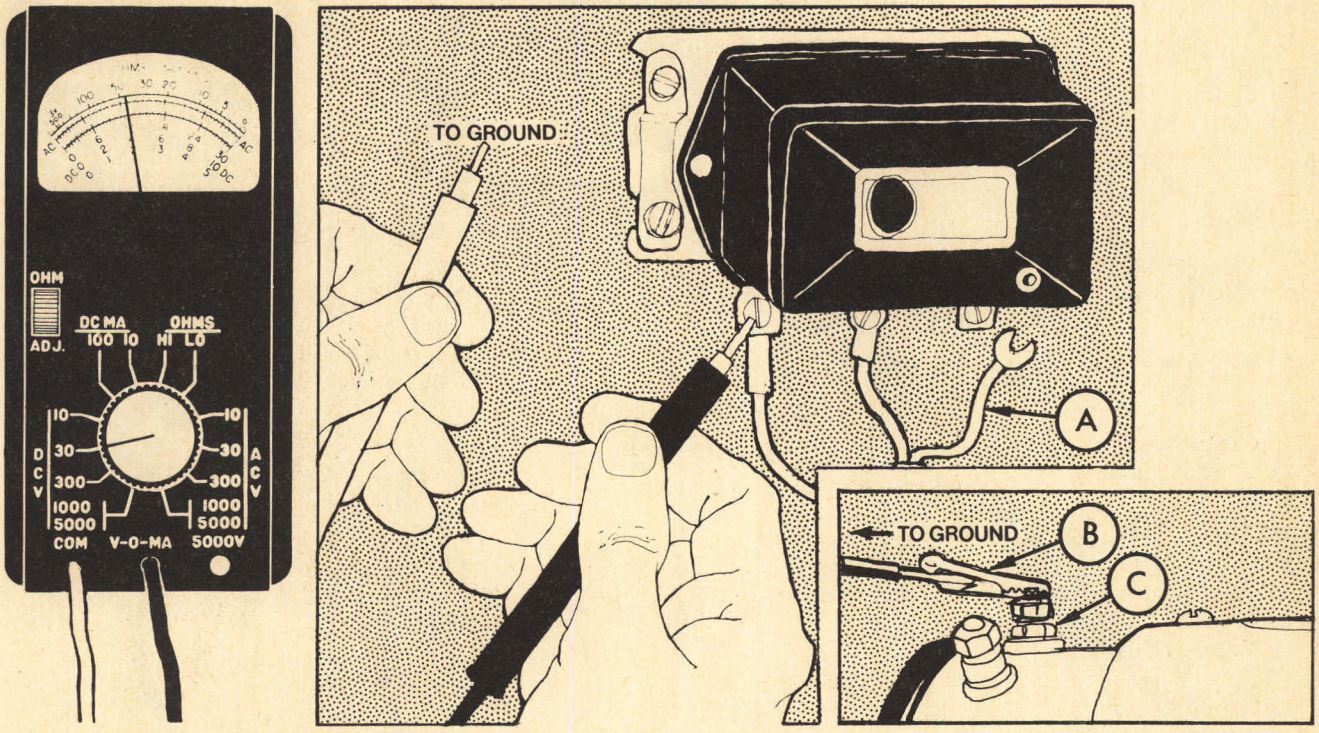
CAUTION: DO NOT EXCEED THE FOLLOWING VOLTAGES BY MORE THAN ONE VOLT. BRING THE ENGINE RPM UP SLOWLY TO AVOID OVERVOLTAGE.

Start the engine and accelerate it until the voltage reads 15.4 volts for a 12-volt system or 7.8 volts for a six-volt system.

If attaching the ground to the FLD terminal of the voltage regulator brings the charging voltage up to the required voltage, the regulator is bad. If grounding the FLD terminal seems to have no effect on the measured voltage, the generator is at fault.

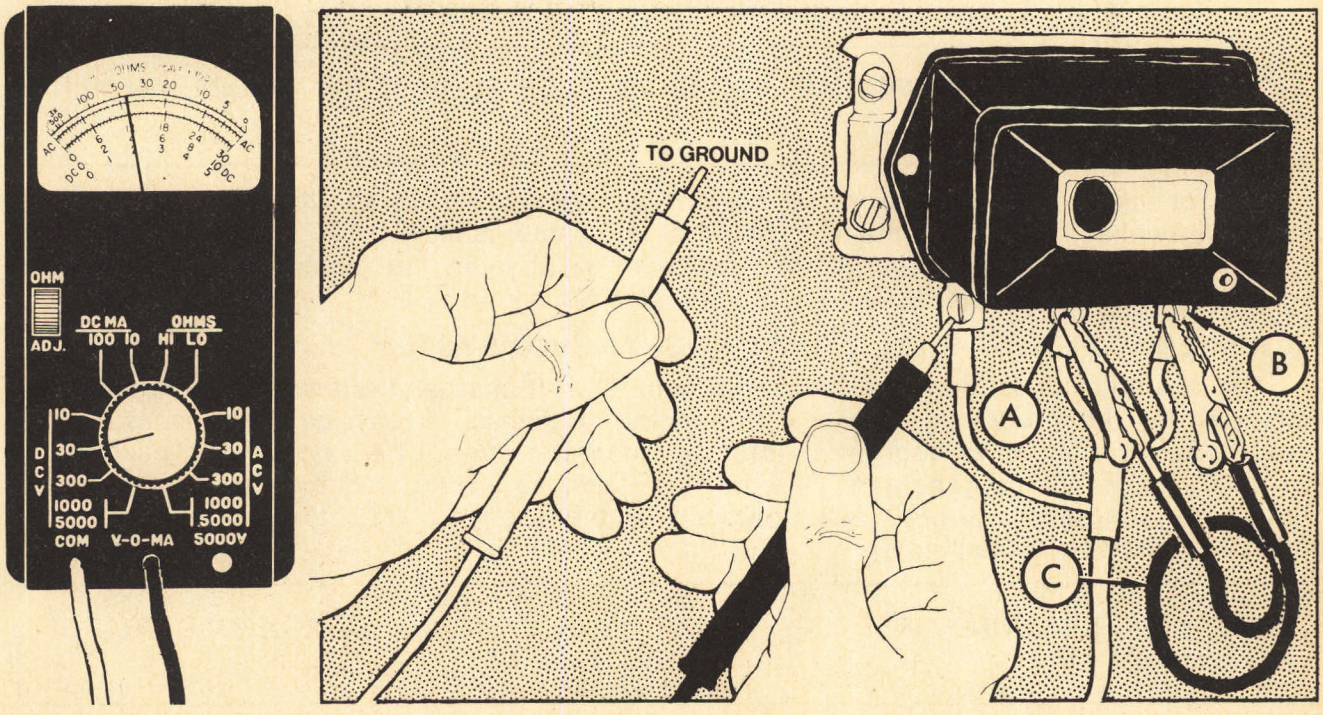
TROUBLESHOOTING THE CHARGING SYSTEM

TESTING THE "A" CIRCUIT DOUBLE-CONTACT SYSTEM



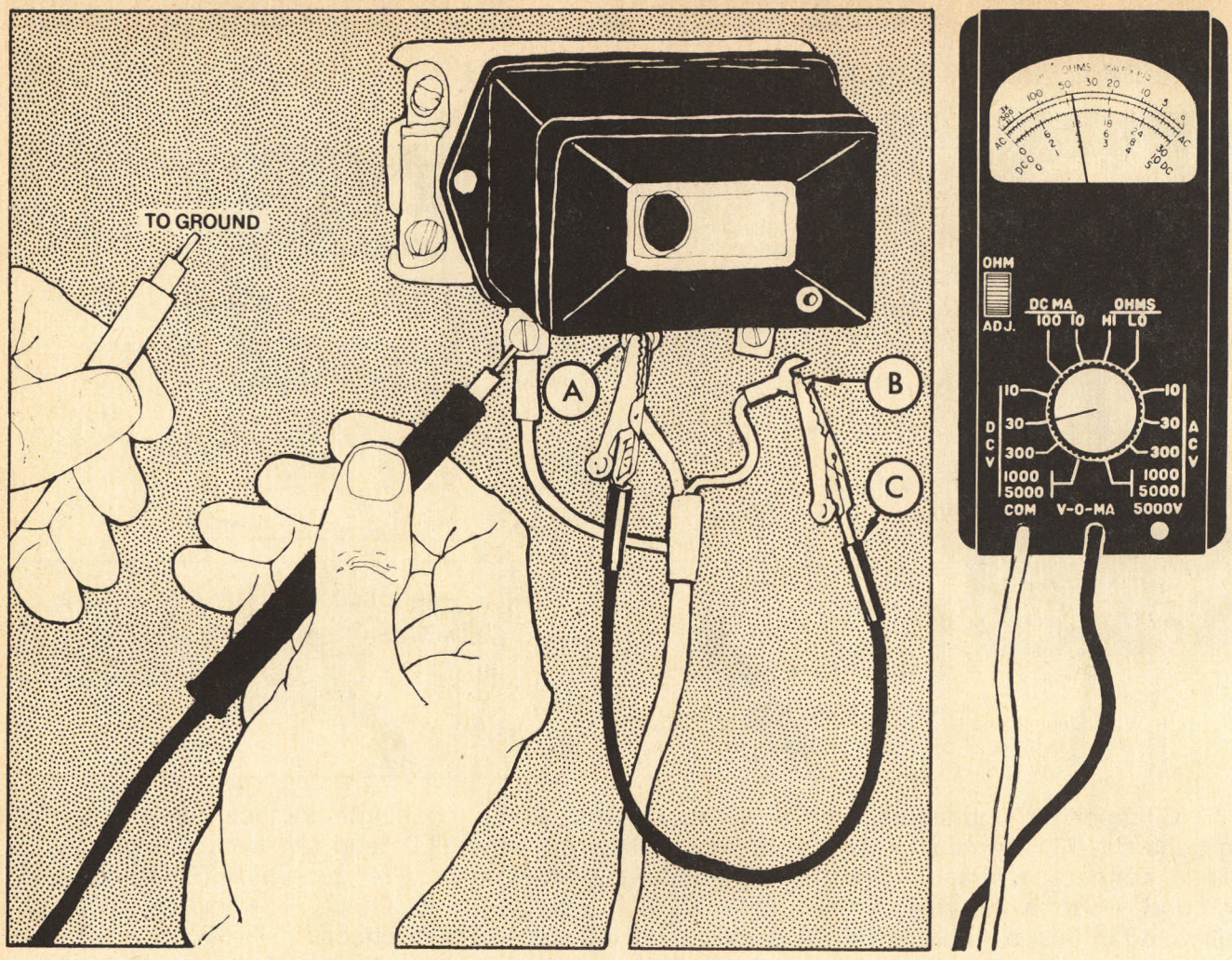
Connect the multimeter in the same manner as in the single-contact check. *Do not* ground the FLD terminal of the regulator. Disconnect the FLD lead (A) from the regulator. Then connect a jumper wire (B) from the FLD terminal on the generator (C) to a good ground. Perform the rest of this check as in the single-circuit check. The voltage readings obtained in this test should be the same as for the single-circuit check.

TESTING THE "B" CIRCUIT SINGLE-CONTACT SYSTEM



Connect the multimeter as in the previous two tests. Connect a jumper wire (C) between the OUT (A) and FLD (B) terminals of the regulator. Then proceed as in the first two tests. The voltage readings obtained should be the same as in the above two tests too.

TESTING THE "B" CIRCUIT DOUBLE-CONTACT SYSTEM



Connect the multimeter as in the previous three checks. Connect a jumper wire (C) from the OUT terminal (A) to the end of the field lead (B) that is disconnected.

NOTE: THE ARMATURE TERMINAL ON THE VOLTAGE REGULATOR MAY BE MARKED "ARM" OR "OUT."

This check is done in the same manner as before, except for the test connections shown. The voltage readings obtained should be the same as in the first check.

After you are satisfied which of the two units is at fault, the generator or the voltage regulator, refer to the shop manual for repair instructions.

TROUBLESHOOTING THE ALTERNATOR CHARGING SYSTEM

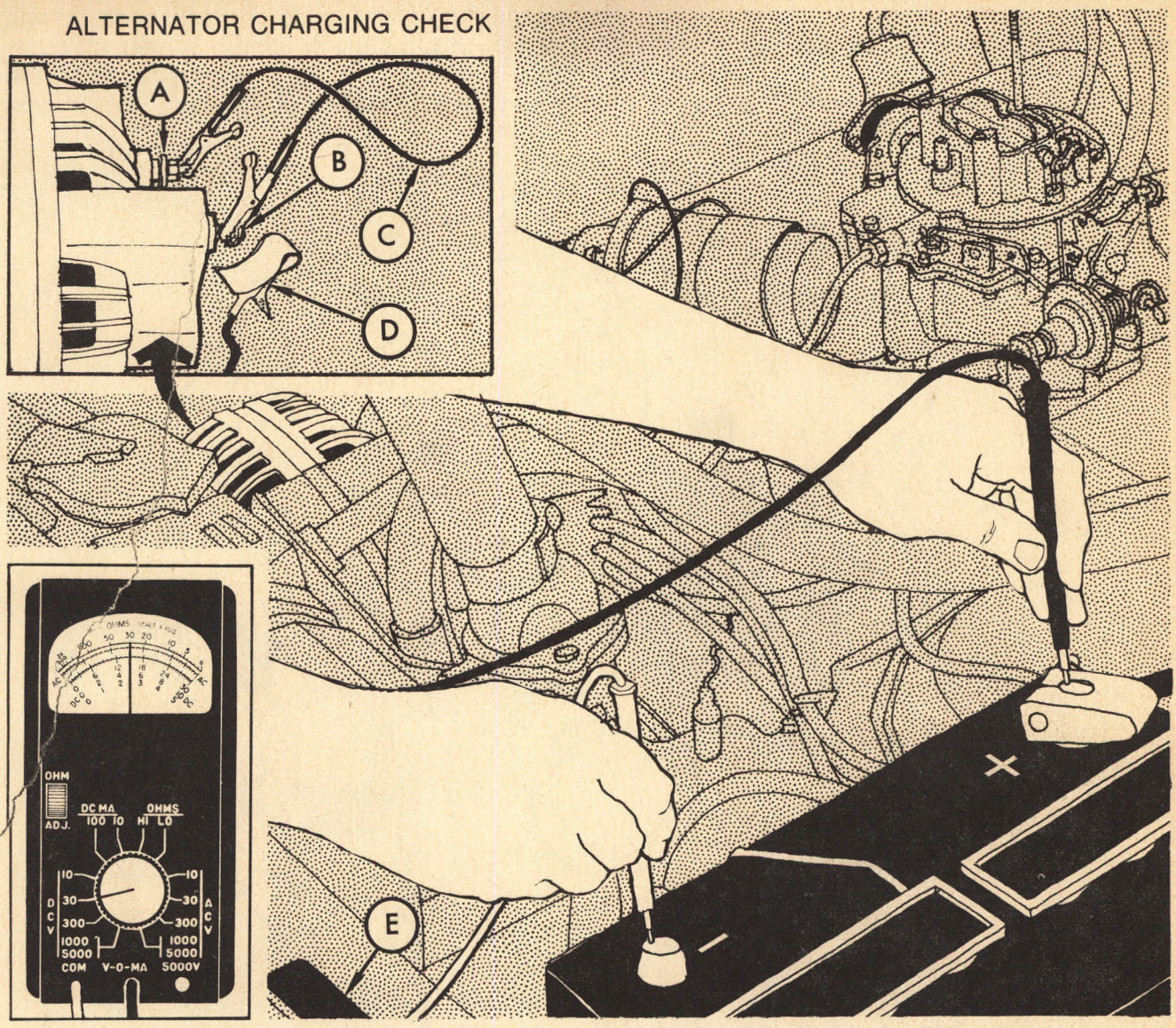
The alternator does the same job as the generator; it charges the battery and provides all electricity for the automobile while it is running. Because of physical differences in the construction of alternators and generators, the alternator cannot be handled and checked in the same manner as the generator. Care must be taken to avoid damage to the diodes, which change the alternating current (AC) produced by the alternator into direct current (DC) for use in the electrical system.

NOTE: NEVER GROUND OR SHORT THE TERMINALS ON ANY ALTERNATOR CHARGING SYSTEM.

After carrying out all of the normal visual checks of the system described in the generator section, you can perform an output check of the alternator which is similar to the ones just performed on the generator.

TROUBLESHOOTING THE CHARGING SYSTEM

ALTERNATOR CHARGING CHECK



Before starting the hookup of the multimeter for the check, disconnect the ground (-) cable from the battery to remove all electricity from the charging system.

On alternators with separate voltage regulators, remove the FLD lead (D) and tape it to prevent accidental grounding of the wire. Connect a jumper wire (C) between the FLD terminal (B) on the alternator and the alternator OUT terminal (A).

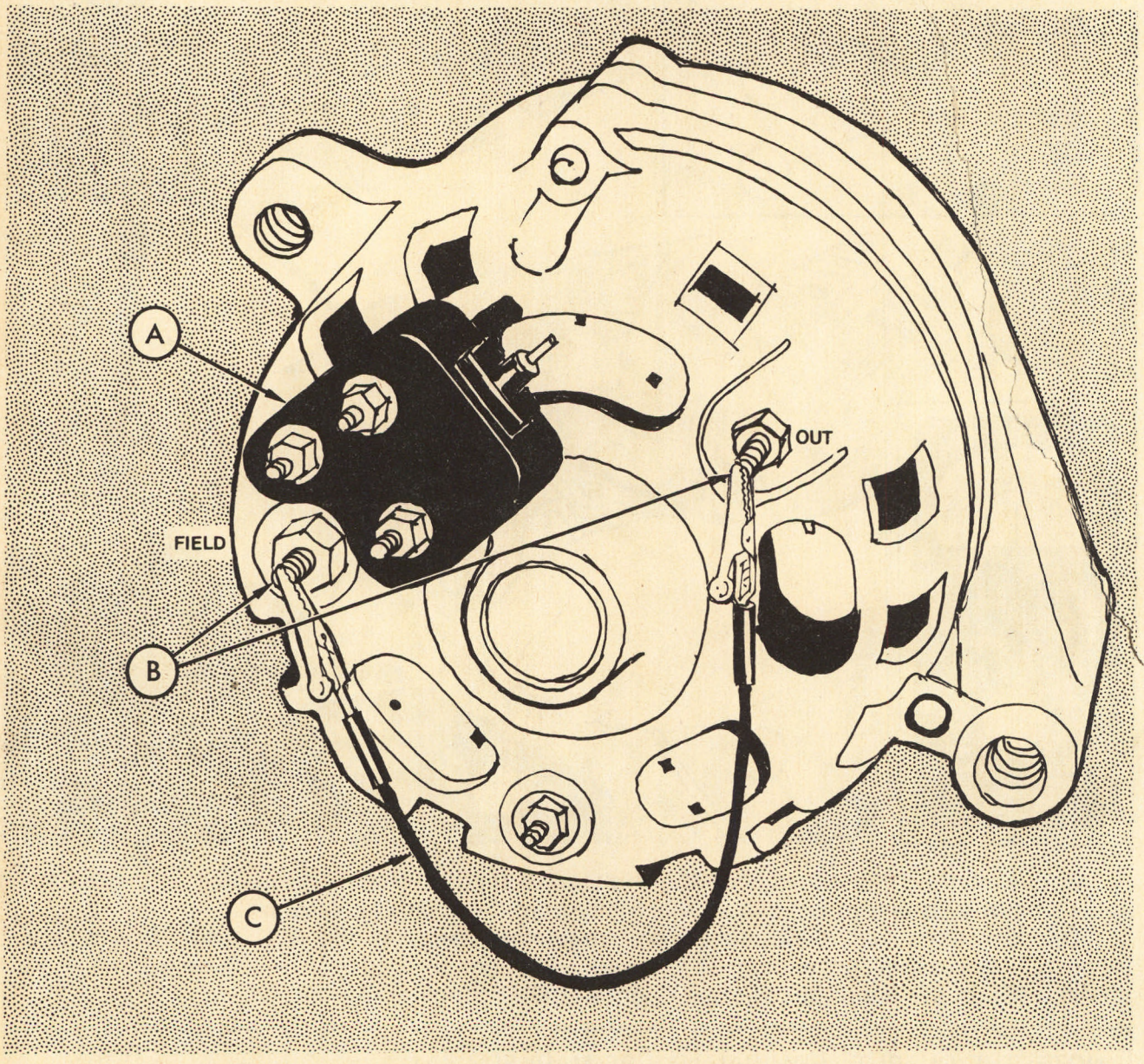
NOTE: THE OUTPUT TERMINAL MAY BE MARKED "BAT," "B" OR "+."

On models that have a protected wiring harness (the connections are inside a plastic plug), disconnect the electrical plug at the regulator and install the jumper wire between the "F" receptacle in the plug and the "3" or "A" receptacle in the plug instead of using the hookup shown.

CAUTION: DO NOT RUN THE ENGINE ABOVE A MEDIUM IDLE WHILE MAKING THIS CHECK. THE ALTERNATOR IS RUNNING WITHOUT PROPER CONTROL AND MAY BE DAMAGED IF ENGINE SPEED GOES TOO HIGH.

Reconnect the battery cable and connect the multimeter as shown in the drawing. Start the engine and test at idle speed or slightly above. The results should be the same as for the

generator test hookups. The meter should show 15 volts charging voltage. However, even a reading of 15 volts may still leave the alternator with a short in one of the diodes (an electrical check valve that allows current to flow in only *one* direction) that changes the alternating current to direct current. Alternator voltage may come up to correct specifications with a bad diode, but the alternator won't be charging the battery properly. If after all other checks have been made, no trouble is found and the system is still not charging properly, the problem may be a bad diode. We do not recommend that you attempt to check the diodes. Take the car to a mechanic and have him check them.



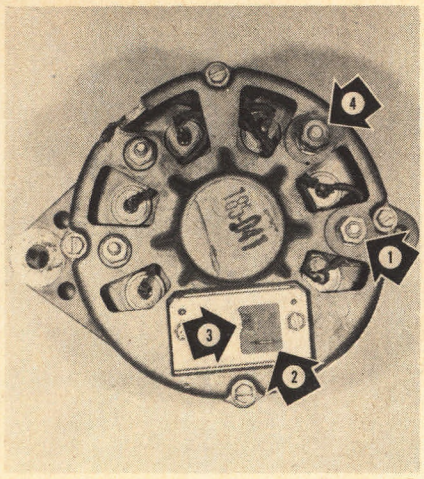
To test an alternator with an enclosed or attached regulator (A), disconnect all wires from the alternator and tape the ends to prevent accidental grounding. Connect a jumper wire (C) to the exposed terminals (B) on the alternator.

If the specified charging voltage is reached with the regulator out of action, the alternator is good. The regulator is the problem.

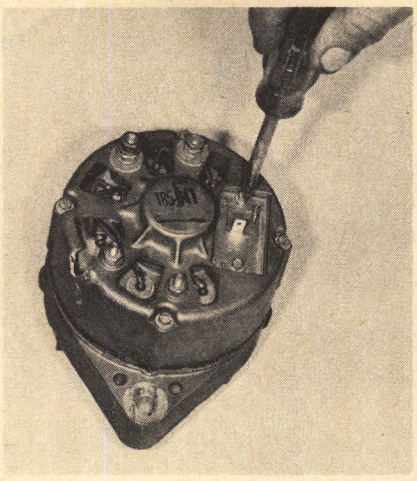
NOTE: ENCLOSED AND ATTACHED REGULATORS ARE ON THE WAY OUT. ONE OF THE REASONS IS THAT WHEN YOU ATTEMPT TO USE JUMPER CABLES TO START YOUR CAR, YOU WILL BURN OUT THE REGULATOR UNLESS ALL LIGHTS AND ACCESSORIES ARE TURNED ON *BEFORE* DISCONNECTING THE JUMPER CABLES.

After you have discovered which of the units is bad, refer to the shop manual for repair instructions.

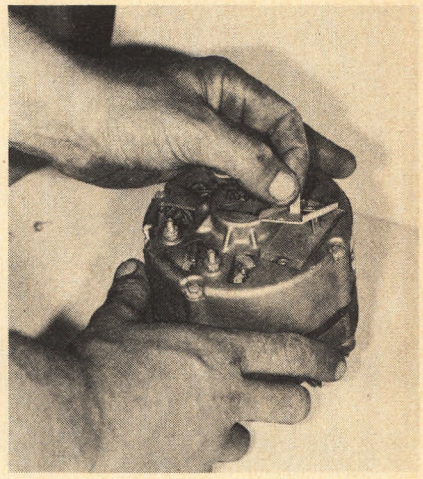
HOW-TO: AMC Alternator Repair



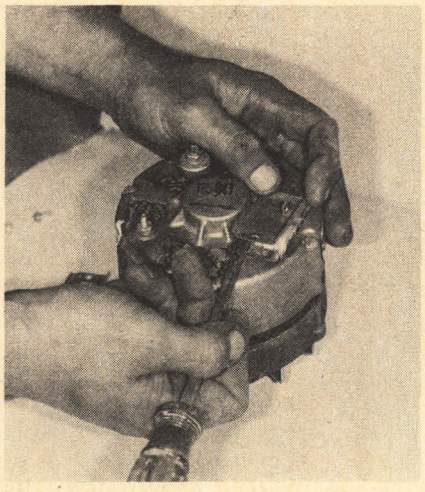
1. Disconnect plug at regulator (1) and at terminals (2,3). Run hot wire to (2). Engine at 2000 rpm should give 15 volts at output terminal (4).



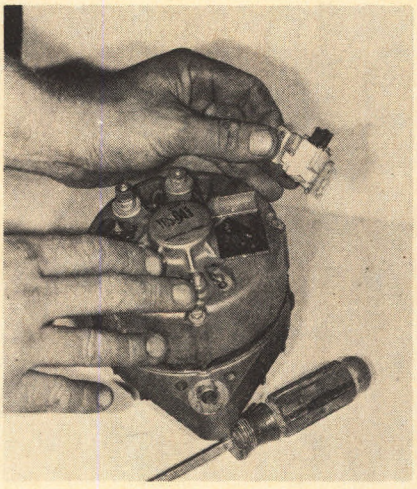
2. To remove and replace the brushes, the first thing that you have to do is remove the two screws that hold the terminal plate in position.



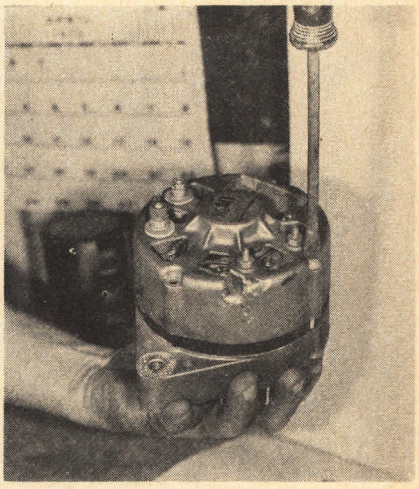
3. The plate with ground terminal attached lifts right off once screws are removed, but you may have to jiggle plate a bit first time around.



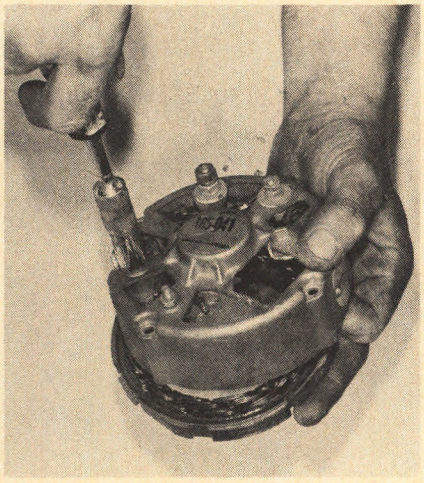
4. Underneath the terminal plate, you'll find an insulator. This is a very important piece; don't forget to replace it and don't lose it.



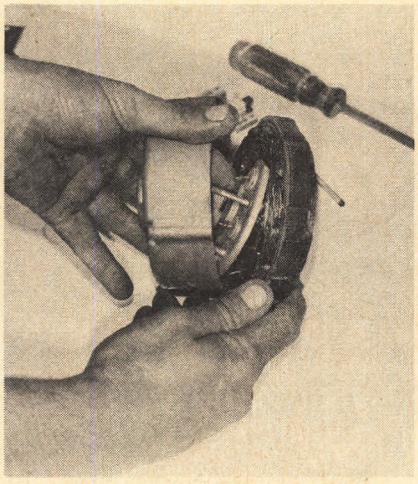
5. Nothing further is required to get to the brushes. Assembly lifts out with ease and replacement brushes are a relatively simple slip-in.



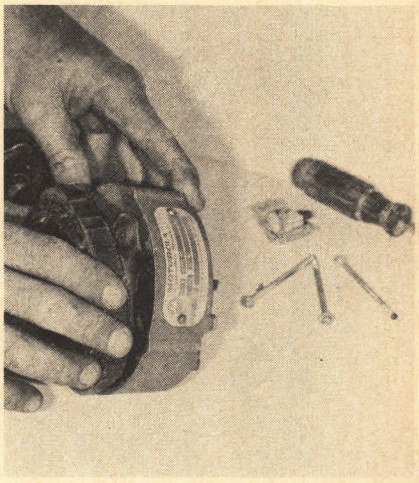
6. Removal of four through-bolts is necessary to split the housing. As with any alternator, mark position of housings for correct assembly.



7. Disconnect terminals that come through the housing to remove diode plate. Lay out variety of washers in the order of removal to avoid mistakes.

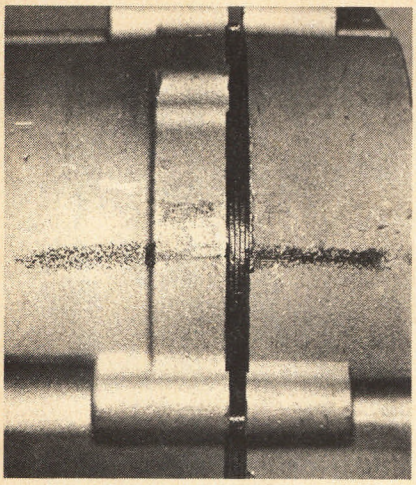


8. Unless you want to unsolder diode leads, this is as far as you can go. If diodes or stator have to be changed, you'll have to unsolder leads.

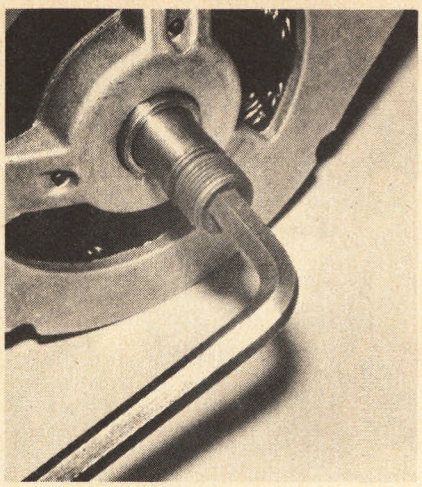


9. American Motors uses a Motorola charging system. ID plate on side contains alternator rating and information needed for replacement parts.

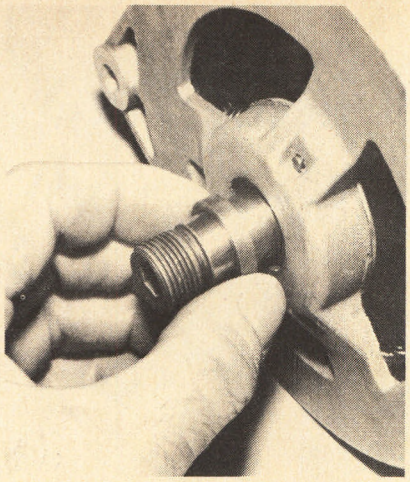
HOW-TO: Delco Alternator Repair



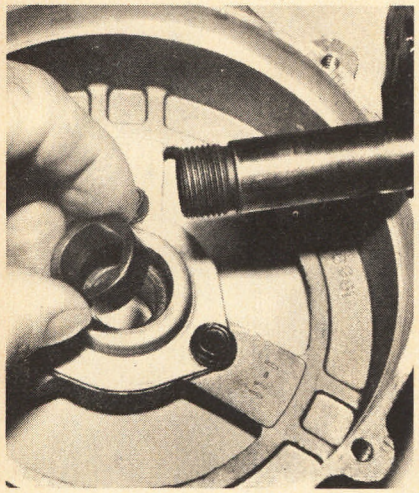
1. Always mark across housings before splitting halves. Assembly will be easier if the housings are put back together the same way they came apart.



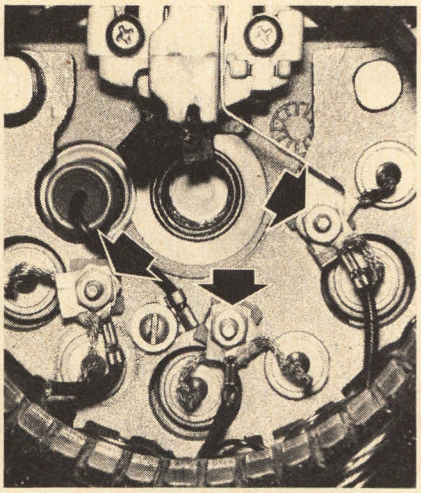
2. Never clamp pulley in a vise. Use an Allen wrench in the end of the shaft, and the pulley nut can be removed with hardly a grunt or groan.



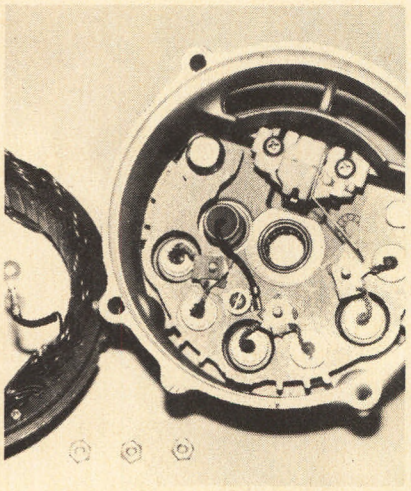
3. Spacer ring is important. It keeps pulley fan from scraping on housing. Rebuilt alternators may come without pulley or spacer, so save old ones.



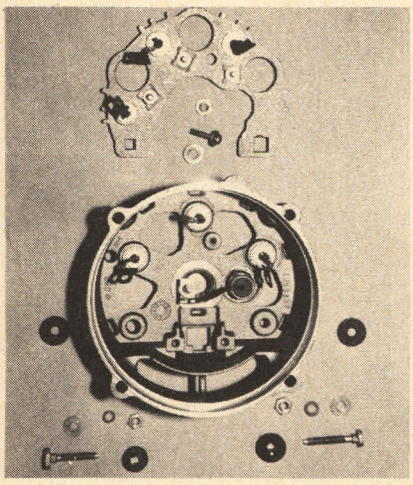
4. Surprise! There's another spacer inside. Three capscrews hold felt dust shield and keep bearing in housing. Bearing taps out of housing easily.



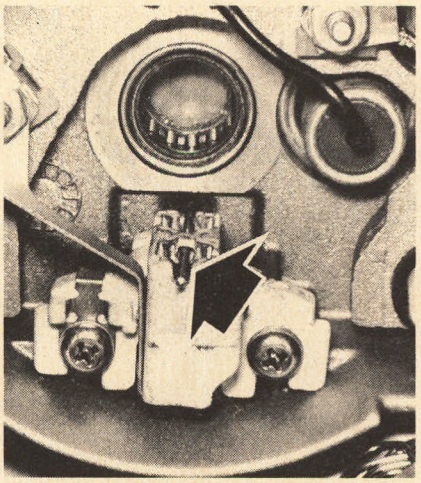
5. Take out four through-bolts, remove drive-end housing with rotor, and this is what you see. To remove stator, take off three nuts (arrows).



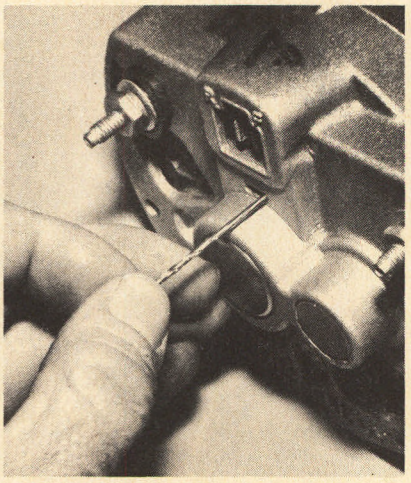
6. With the stator out of the way you can see the diodes, and with their leads disconnected, you can now easily test them with a battery test light.



7. Positive diodes are pressed into the plate, and negative are pressed into the housing. Pressing diodes in or out requires special tools. Don't hammer!

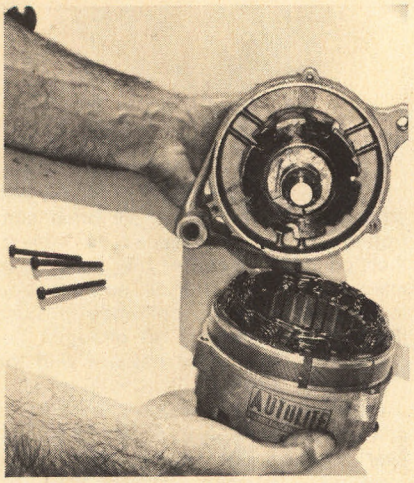


8. To reassemble, brushes must be held down in holder with drill bit pushed in from outside housing. Do it carefully so you don't damage brushes.

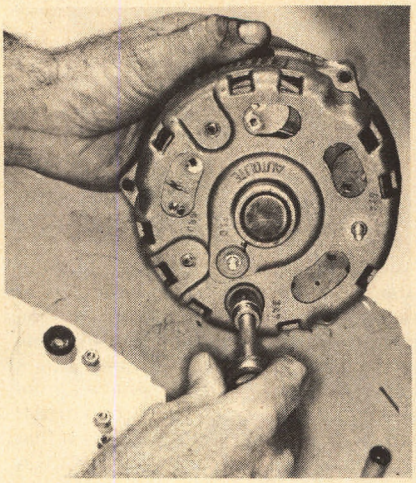


9. Line up housing marks, put bolts back in, then pull drill bit out and brushes will go against rotor slip rings. Your alternator job is finished.

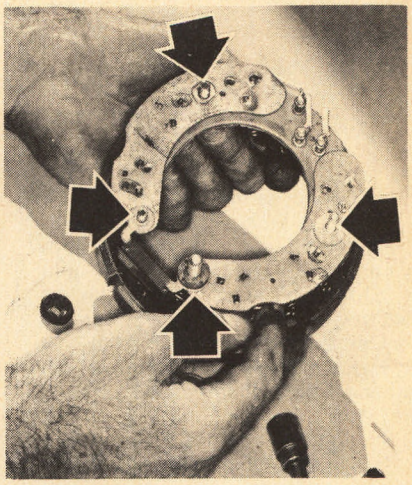
HOW-TO: Ford Alternator Repair



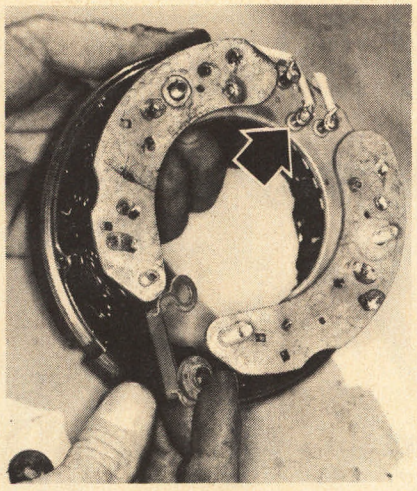
1. Three bolts hold the Ford-Autolite alternator together. Be sure you mark the housings before disassembly. Rotor comes off with drive-end housing.



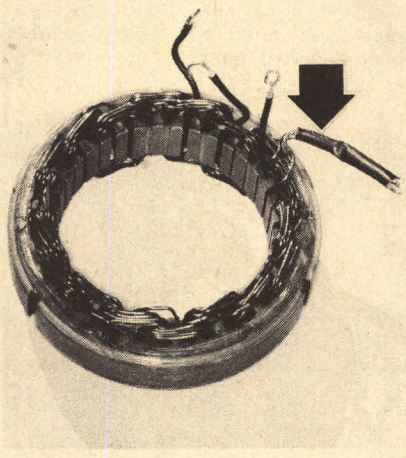
2. Stator and diode plate are removed as a unit, but first you have to collect an endless number of nuts, steel washers, and insulating washers.



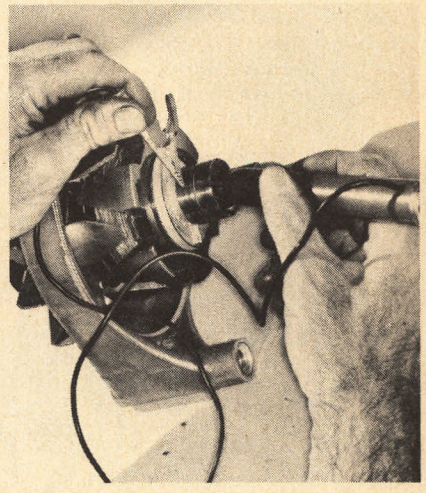
3. Arrows indicate the four posts that attach the diode plate to the housing. All posts and washers must be assembled exactly as removed, or it's no charge.



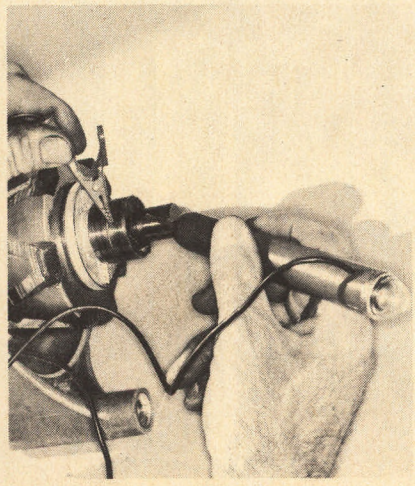
4. Little box is really a condenser. Arrow points to three stator leads that are soldered to diode plate. If any diodes are bad, entire plate is changed.



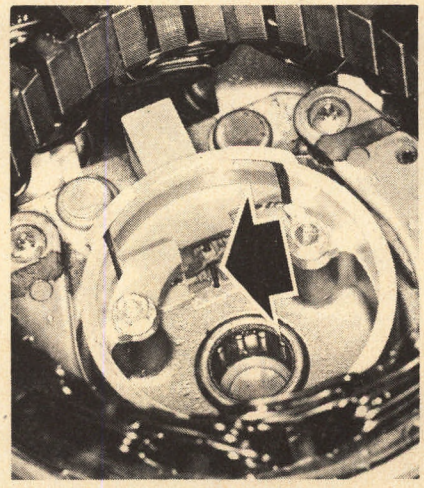
5. Removing diode plate reveals an extra lead. It is the Y connection between the three stator phases. It should be tucked away, insulated from ground.



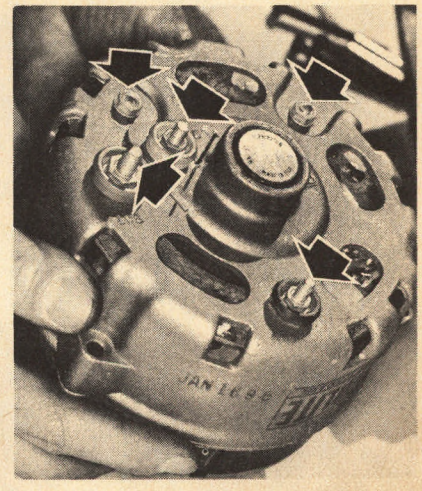
6. Testing rotor for continuity. Test bulb should light when probes are put on both slip rings. If no light, the rotor must be changed.



7. Testing rotor for ground, with the probes on shaft and one slip ring. If bulb lights, rotor is grounded, and must be changed.



8. To reassemble, load brushes into the holder with springs underneath, then slip drill bit in from outside housing. Work carefully, don't damage brushes.



9. After assembly, bit is pulled out to allow brushes to ride on slip rings. Note the five posts (arrows). Some are insulated, some not. Don't mix 'em.

Lights, Gauges, Wiring

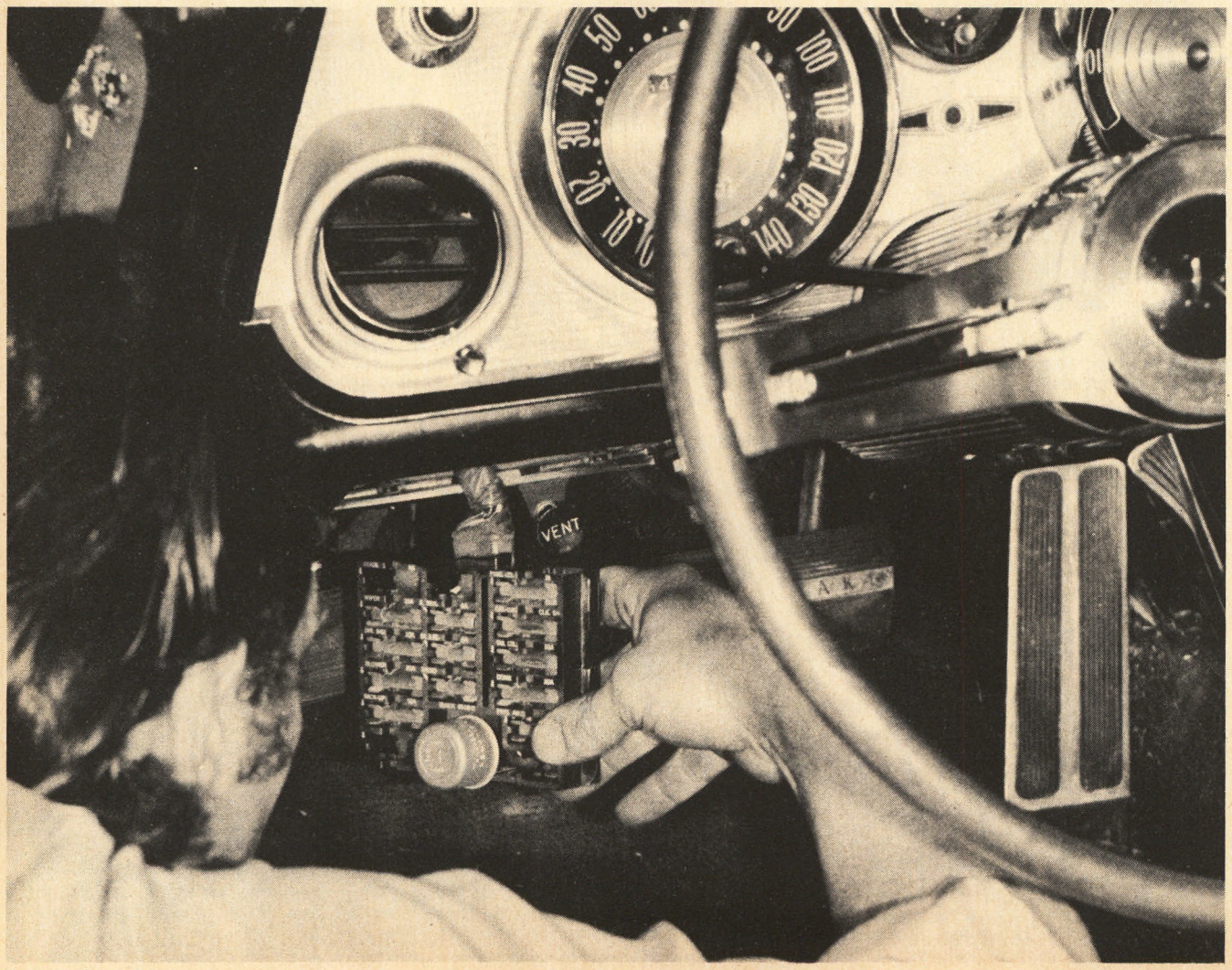
This chapter is the do-it-yourselfer's paradise. Since the first automobiles came out, car owners have been carrying spare fuses, spare light bulbs, and maybe even doing a little bit of their own wiring when they want to add an accessory. If you're a little bit timid about working on some of the more complicated units of the car such as the starter, the generator or engine parts, the lighting system is a good place to get started and build up your confidence. It's also a good place to practice ahead of time so that when a headlight or even a fuse burns out in the middle of the night you have a pretty good idea of what you have to do to fix it. The wise driver will keep a roll of electrical tape, extra fuses, a spare sealed beam headlight unit, and some simple tools in the car at all times to cope with any highway emergencies that may come up.

FUSES AND CIRCUIT BREAKERS

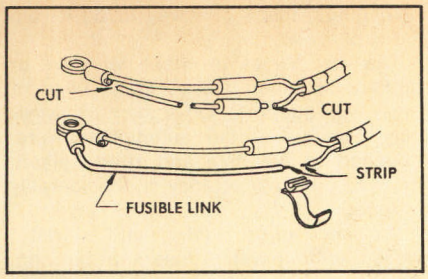
A fuse is nothing more than a glass or ceramic insulator with metal contacts at the ends which are connected to one another electrically by fine wires or thin metal strips. The latter will melt like a chorus girl's heart at a millionaires' convention, if a precise electrical current load is exceeded. Short circuits that might otherwise transform your car's wiring into a Fourth-of-July display of flaming spaghetti are quickly "switched off" when the fusible wire burns apart.

Lately, car makers have been eliminating many fuses in favor of circuit breakers. The circuit breaker is basically an electro-mechanical device that functions as a fuse does, but has the added advantage of being able to restore the flow of electricity automatically once the trouble is past. Headlights, wipers and other safety accessories are often controlled by circuit breakers to prevent their complete failure in the event of an intermittent short. After all, no one wants to have his lights go out while crossing the Nevada desert at 90 per—just because something went haywire with the cigarette lighter!

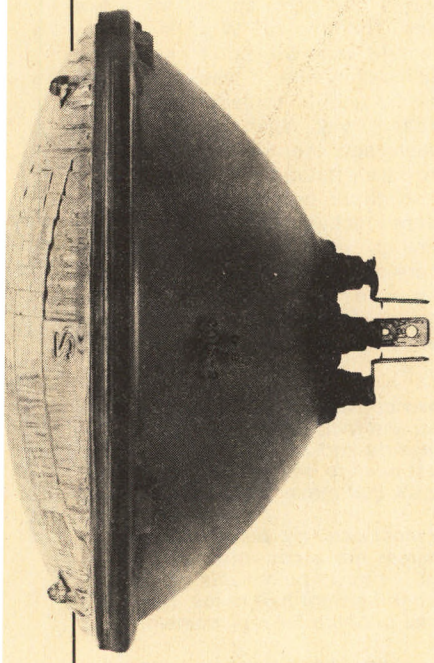
Circuit breakers are sealed assemblies and should one go bad (which seldom ever happens) the whole unit must be replaced. Just make certain that you install a new one of the identical type and amperage as the original. In many cases the circuit breaker is an integral part of the headlight switch, in which case that part must be replaced in its entirety. Late GM cars have a release button on the switch behind the dash which, when pushed, allows the light control knob and shaft to be pulled completely out of



1. Fuse Block Under Dash



2. Fusible Link Repair



3. Headlight Connections

1. You're most likely to find the fuse block under the forward edge of the instrument panel. Carrying a few extra fuses can be a lifesaver in case of an emergency.

2. Repair damaged link by cutting as shown. Strip insulation back, splice wires with a splice clip and then solder. Be sure to tape splice with a double layer of electrical tape.

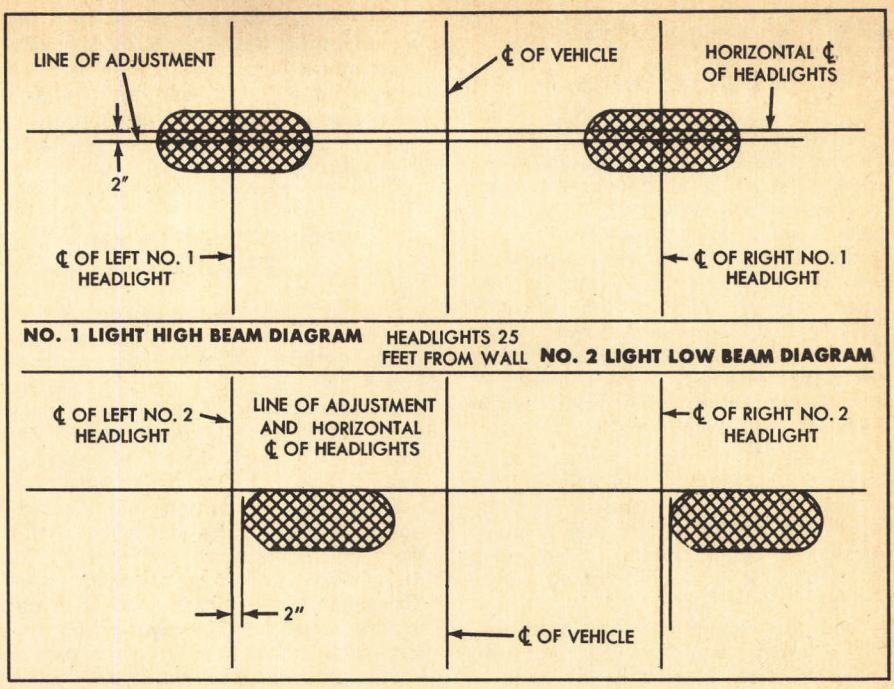
3. Most headlights have two or three prongs for connection. The third one on this sealed beam is for a ground. It's usually connected to the shell of the headlight, but can be switched to the car body for a better ground.

4. Draw this diagram on your garage door, and you can do your own light adjusting right in your driveway, as long as the pavement is level.

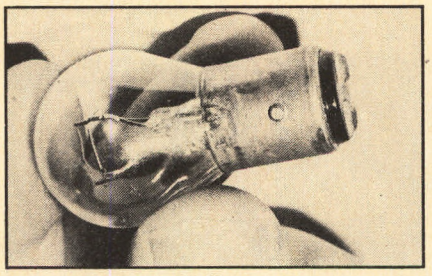
5. Note the two terminals on this typical twin-filament bulb. Sockets for these will have two wires; one may be for stoplight filament, the other for turn signal or taillight.

6. Most bulbs ground through socket. If the bulb doesn't work, check the filament first and if it's all right, then clean any corrosion from socket.

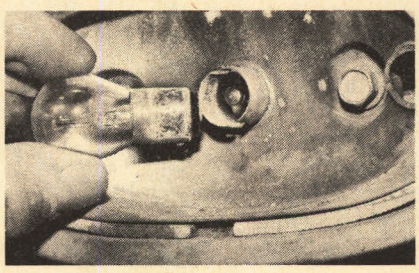
7. Probably the most popular gauge sold on the aftermarket is the tach. This Auto Meter unit features rubber in the mounting for anti-vibration.



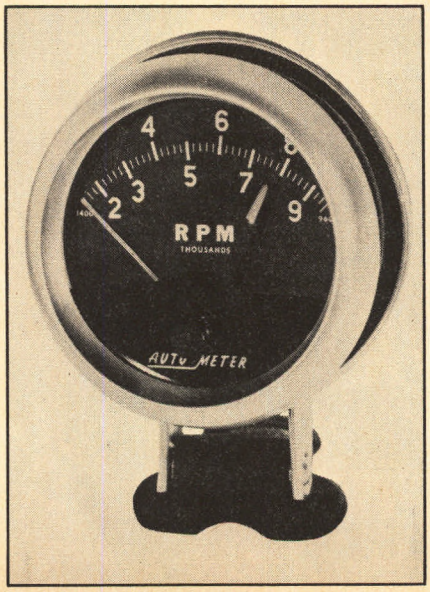
4. Headlight Aiming Chart



5. Twin-Filament Bulb



6. Corroded Socket



7. Auto Meter Tachometer

the dashboard before removing the retainer ring that mounts the switch on the car.

The majority of American cars have their fuse panel located under the forward edge of the dashboard. On some models the fuse panel is located on the firewall just above the driver's feet. Most fuse panels have each fuse marked according to its function (radio, heater, etc.) and its amperage. Check the ampere rating for the fuses in your car and buy a few extras to slip into the glove compartment. This simple act could save you lots of trouble.

On many fuse blocks there isn't enough room to label all of the circuits that the fuse protects. Only the most prominent item, such as the radio or the wipers will be printed on the fuse block. If some electric unit on your car stops dead, but you can't find a label for that unit on the fuse block, check the wiring diagram in the factory shop manual. In some cases, the owner's manual will give a more complete description of the circuits protected by each fuse. There may also be fuses in some other location, nowhere near the main fuse block.

A fuse that blows—or a circuit breaker that cuts out—may indicate either a shorted circuit or one that is being overloaded. If the fuse blows again after it replaces the original, or if the circuit breaker cuts out repeatedly, it's time to plop on your Sherlock Holmes cap and start looking for the source of the trouble. However, if the second fuse doesn't blow, the first incident was possibly only the result of a momentary overload. This may occur on those rare occasions when several accessories sharing a common fuse are in operation simultaneously. Should one accessory begin drawing abnormally high current—as a windshield wiper may when pushing aside heavy snow—the fuse may be momentarily overloaded. A circuit breaker will simply cut the current for an instant and then things should return to their normal conditions.

Lights, Gauges, Wiring

FUSIBLE LINKS

A few years ago it wasn't unusual to hear of a car that had burned up from a short in the wiring. All it took was a bare wire against the frame or body, and the battery would pour out enough current to heat up the wire, set the insulation on fire, and turn your pride and joy into smoldering ashes. It is now extremely unlikely that car fires will ever occur from shorts or grounds in wiring. Every car today has one or more fusible links, that will burn in two if they are forced to carry any overload of current.

The fusible link is a piece of wire about 6 ins. long that is spliced into another wire. The link can be in many different locations in the engine compartment or behind the instrument panel. In some cases it is identified by a special color or a lettered tab. It may be looped so it stands out from other wiring, or it may blend in so you don't even know it's there. Some links can burn in two without any change in appearance, but the better links have a special insulation that bubbles and swells when the wire burns up. New links are available at parts stores and dealers. The old link should be cut out, and the new link spliced and soldered into position. If the new link comes as a piece of bulk wire, it should end up the same length as the old link after being spliced in.

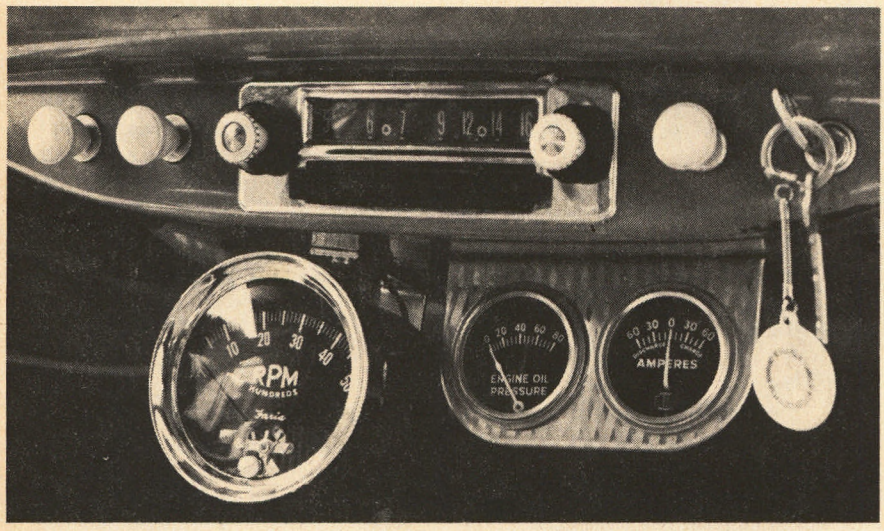
WIRES—SHORTS AND GROUNDS

Shorted wires are the usual cause of blown fuses. Whenever a "hot" (as opposed to a "grounded") wire starts to suffer from worn or frayed insulation, there is a danger of this. Occasionally some Grade "A" boulder-brain will decide it's too much trouble to keep replacing fuses, so he deftly inserts a piece of a 10-penny nail into the fuse holders. It might be better to simply trace down the short, but never mind, that's even harder than changing fuses. This knot-headed trick burned up a car in New Jersey just a few years ago. Unfortunately, it was parked in the garage under the owner's new split-level house at the time. If you want to start fresh with a new house and car, plus all your belongings, that's one way to do it—but it's expensive.

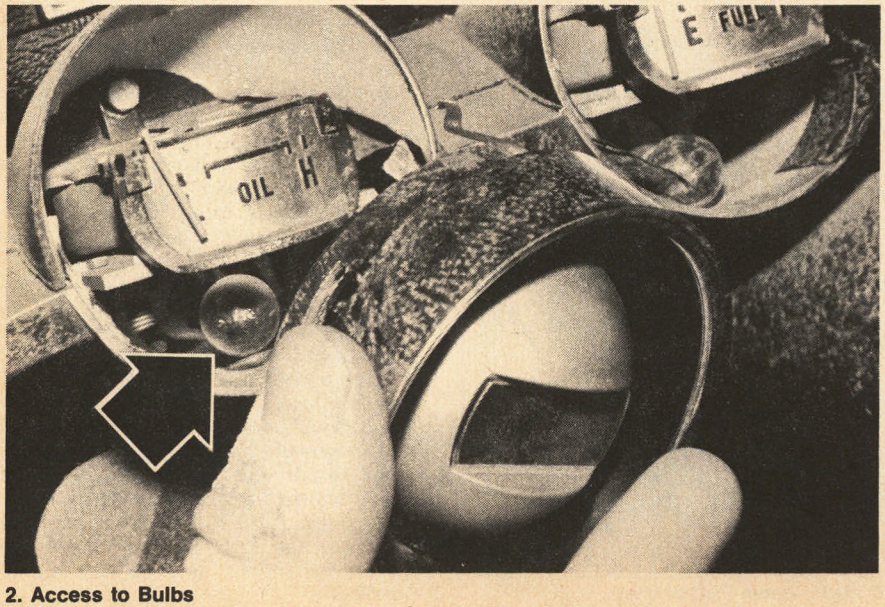
The first places to check for worn or broken insulation are at metal clips or other wire supports. On some cars, wires may pass *under* the automobile. Here, exposed to weather and road splash, the wire's life expectancy is considerably reduced.

We were once driving with a friend whose lighting-system fuse kept blowing. After using several fuses, repeated taping and inspection of the wires, and much soul-rousing profanity, we finally noticed that the fuses only blew when the brakes had been applied for a few seconds. The trouble? Worn insulation on the one wire we didn't check—the stoplight switch wire. It was located under the car and its insulation had practically rotted away. When the brake pedal was depressed, the arm on the stoplight switch barely touched the wire, but it was enough to produce a shorted circuit. Three inches of plastic tape around the wire got us home, and a new wire took care of the problem.

Other wire trouble is frequently encountered at the terminals. Corrosion and vibration can eventually produce



1. Accessory Gauges



2. Access to Bulbs

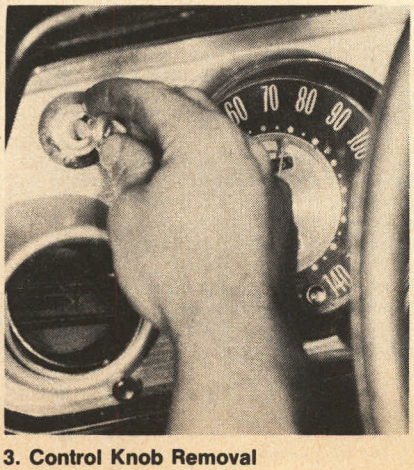
1. When considering extra gauges to supplement factory instrumentation, oil pressure and ammeter gauges are the first ones to get, and are available in panels that mount below the dash.

2. On most cars, the bulbs that light the gauges are accessible only from behind the dash, but on this model removing the front half of the gauge exposes the bulb for replacement.

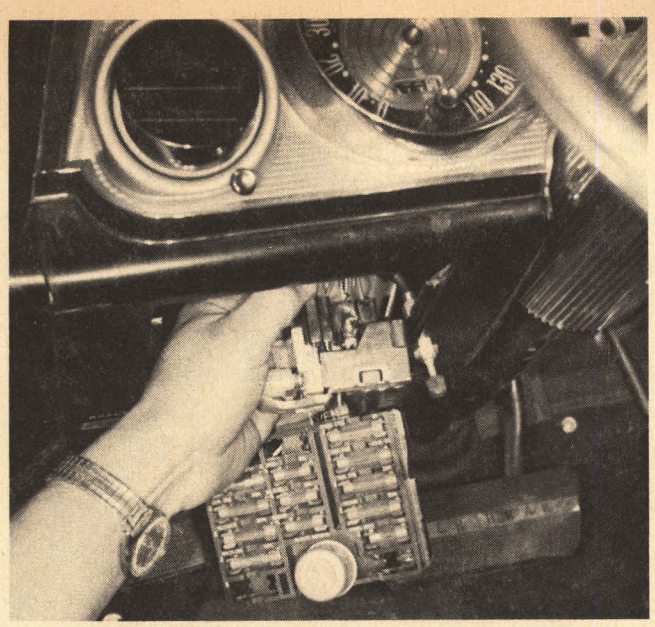
3. The control knob must be removed before replacing switches mounted through the instrument panel. This Buick knob comes out when button on switch body is depressed.

4. Fuse block has to be dropped to gain access under dash. After knob is removed, a retaining clip is popped off from behind, and the unit can then be removed.

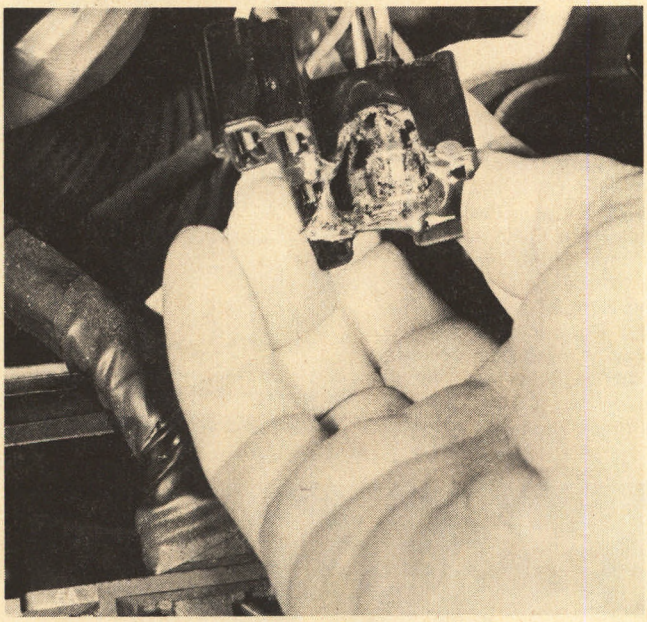
5, 6. Bakelite connector has burned itself out. Faulty connection between this and the switch (6) allowed constant arcing that ruined both units and presented a definite safety hazard in terms of fire as well as lights that fluctuated while in use.



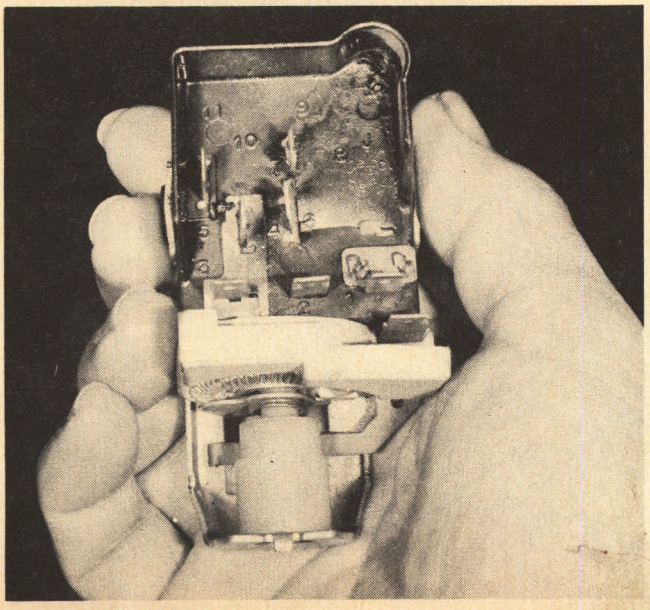
3. Control Knob Removal



4. Fuse Block Removal



5. Burned Bakelite Connector



6. Burned-out Switch

GUIDE TO FUSIBLE LINKS

MAKE	LOCATION	COLOR
AMC	Battery terminal of starter relay to main wire harness	RED
	Battery terminal of horn relay to main wire harness	PINK
	Accessory terminal of ignition switch to wire harness	BROWN
	Battery terminal of starter relay to heated rear window relay	RED
	B-3 terminal of ignition switch to circuit breaker	RED
	I-3 terminal of ignition* switch to circuit breaker	YELLOW
	I-3 terminal of ignition* switch (single wire at the switch splits into two feed wires)	YELLOW
	I-3 terminal of ignition* switch to throttle stop solenoid	YELLOW
	*Only one of these links is used on any one vehicle.	
BUICK	Battery terminal of starter solenoid to lower end of main supply wires	BLACK
CADILLAC	Battery terminal of starter solenoid to main wire harness.	
CHEVROLET	Molded splice at solenoid battery terminal	BROWN
	Molded splice at horn relay.	BLACK
	Molded splice in voltage regulator #3 terminal wire	ORANGE
	Molded splice in ammeter circuit (both sides of meter)	ORANGE
CHRYSLER	On battery terminal of starter solenoid	DARK BLUE
	Above bulkhead connector	DARK BLUE
	Between battery and terminal block.	DARK GREEN
FORD LINCOLN MERCURY	Between starter solenoid battery terminal and alternator (Mustang and Cougar only).	
	Looped outside wire harness between starter solenoid and alternator (T-Bird and Lincoln only), behind point at which harness is dipped to the right rocker cover (above starter).	
	Twin links between starter solenoid and alternator (1) and starter solenoid to vehicle equipment harness.	
OLDSMOBILE	At horn relay jet block (All except Omega)	BLACK
	Twin links at horn relay jet block (Omega only)	BLACK/ORANGE
	At starter solenoid battery terminal (Omega only)	BROWN
PONTIAC	Positive battery cable pigtail lead (requires entire cable replacement).	BROWN
	At horn relay	BLACK
	Molded splice in circuit at jet block and horn relay (some single and some twin)	ORANGE

poor contact. A regular check for terminal tightness, and a cleaning with abrasive cloth when trouble strikes, will usually prevent most of the bad contacts. Broken wires can be repaired in one of three ways. First—and best, if the insulation is in generally poor condition—is to replace the wire in its entirety. Wires can be spliced by simply twisting the ends together, soldering the joint if possible, and covering the area with electrical tape. A coating of liquid rubber over the taped joint will make a very permanent and weatherproof joint. In some cases it is possible to install a crimped-on splicing tube. These, however, require a special tool to compress them.

A very great variety of specialized wire terminals are available from automotive supply stores. These must be crimped into place with a special tool. Such terminals require no soldering, and their addition will always insure a flawless connection.

HEADLIGHTS

Replacing a burned-out sealed beam unit is perhaps the simplest of automotive repairs—next to changing fuses. Still, more "first time" home mechanics have botched this job than would ever care to admit it to even themselves.

Dual headlight installations employ two different types of sealed beam units. The high beam lamps which "go out" when the headlights are dimmed, have only two terminals on the back, and their lens is marked with a number "1." The other units operate on both high and low beam, and like the sealed beam lamps found on cars with single headlights, they have three terminals on the back. The lens of these is marked with a number "2." Before buying a new one, be sure you know if you're replacing the high/low #2 lamp or the high beam #1 lamp only. On cars with the dual lights arranged side by side, the outermost lamps are the 3-terminal high/low combination. On Pontiacs, Plymouths and other cars that have one light mounted above the other, the high/low #2 unit is the upper one.

The first step in making the actual replacement is to take off the decorative trim surrounding the headlight. On most cars with dual lights there are three or four screws used to do the job. Cars with single lights usually have only one screw directly at the bottom of the chrome ring. Once the trim is off, there will be several screws visible around the circumference of the headlight. Three of these will be removed to change the sealed beam unit. The other two must not be tampered with since they are for aiming the lights. These aiming screws are larger than the retaining screws and are therefore pretty easy to spot.

Once the retaining ring surrounding the light is off, the sealed beam unit can be pulled out and the plug withdrawn from its terminals. Putting in the new lamp is simply a reversal of the removal process, but be sure to position the lens so that the word "TOP" is at the top where it is supposed to be.

HEADLIGHT AIMING

Twenty years ago the highways were peppered with immature squirrels who deliberately aimed their car's headlights in a way calculated to blind other drivers. Quite a few even mounted spotlights for this very purpose. If your lights were brighter than the other guys, you were a bigger man. Or at least brighter.

Well, the police finally got tired of hauling dozens of these rabbit-brained anthropoids off to the cop shop every night, and state legislators passed laws in many locales that required car owners to either obtain a certificate to the effect that their headlight aiming had been carried out by a "professional," or to have the headlight aim checked annually by state-licensed inspectors.

If you live in one of these areas where the government is trying to save the populace from its own folly, there's not much you can do about aiming your own headlights unless only a state inspection is required. However, if there are no such legal requirements in your particular state, you can do your own headlight aiming with relative ease.

You'll need to find a place where your car will sit level, such as a paved driveway or parking lot. Or you can drive your car to such a place and lay a carpenter's spirit level on the front bumper and on one of the door sills (with the door open). Even on a level surface, the car may not sit absolutely level, or the bumper may be mounted in a slightly tilted position in relation to the car, so mark the location of the bubble in the level with a grease pencil. Rock the car from side to side and allow it to assume its normal attitude before making the tests with the spirit level.

The car can then be driven home to

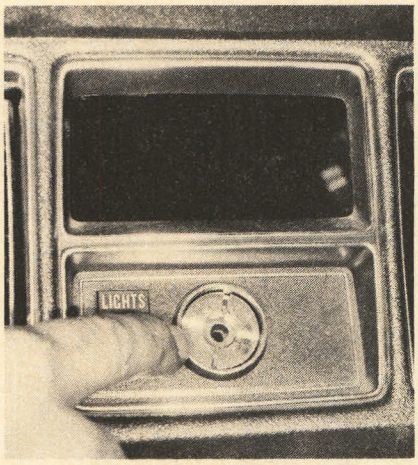
1. Some switches are more difficult to get to. Radio has to be pulled to allow arm access behind dash for this light switch to be removed.

2. Rear view of the same dash panel shows how light switch (1) is placed. Wiper switch (2) and signal light (3) can be taken out withoit removing panel, but steering column must be dropped, and as you'll be working blind, expect bruised knuckles.

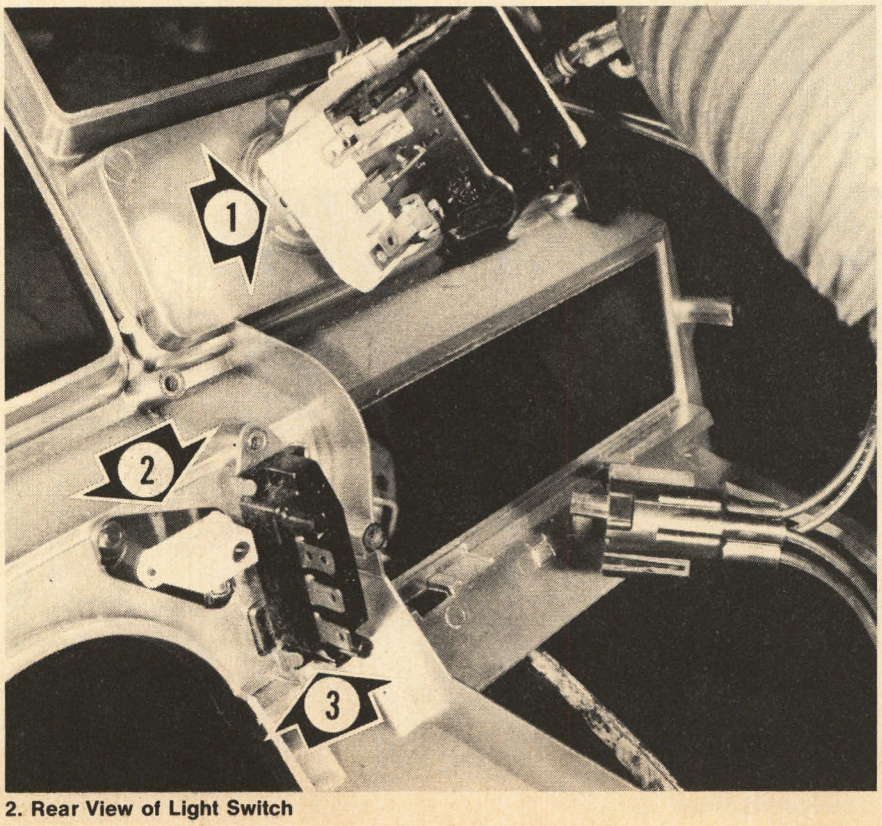
3. Late-model speedometers have a thumb latch for disconnecting the cable, instead of the old-fashioned type with a threaded ferrule.

4. Most gauges can't be taken apart for repairs, but this fuel gauge can be adjusted with a small screwdriver.

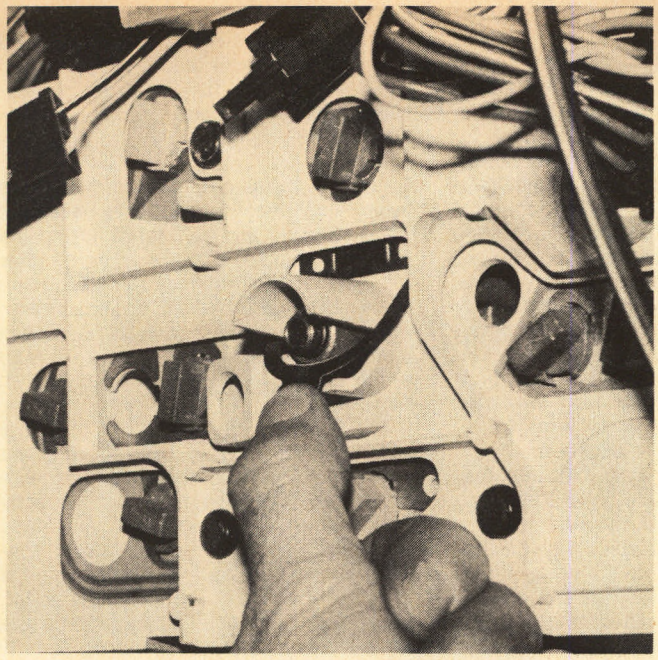
5. Here's an example of well-planned and well-executed wiring job on a custom dash with many gauges. Note the use of neat wire bundles and wiring terminal blocks.



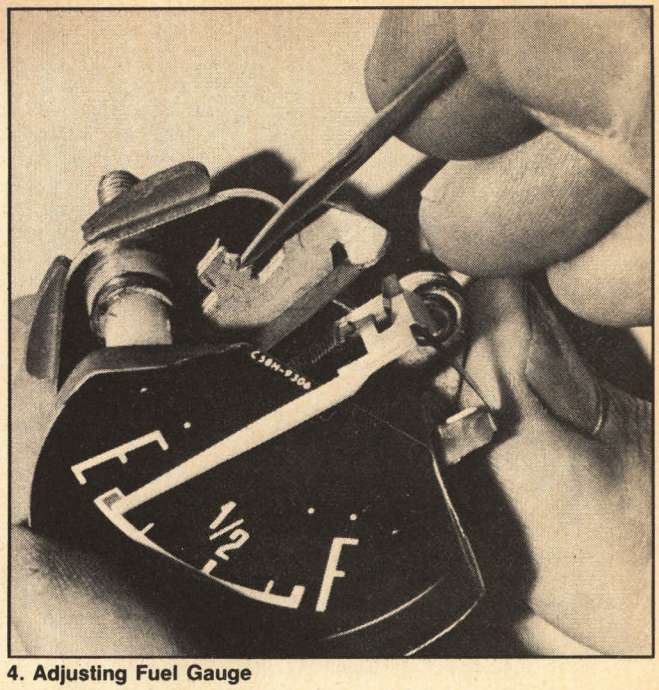
1. Light Switch Removal



2. Rear View of Light Switch



3. Speedometer Cable Connection



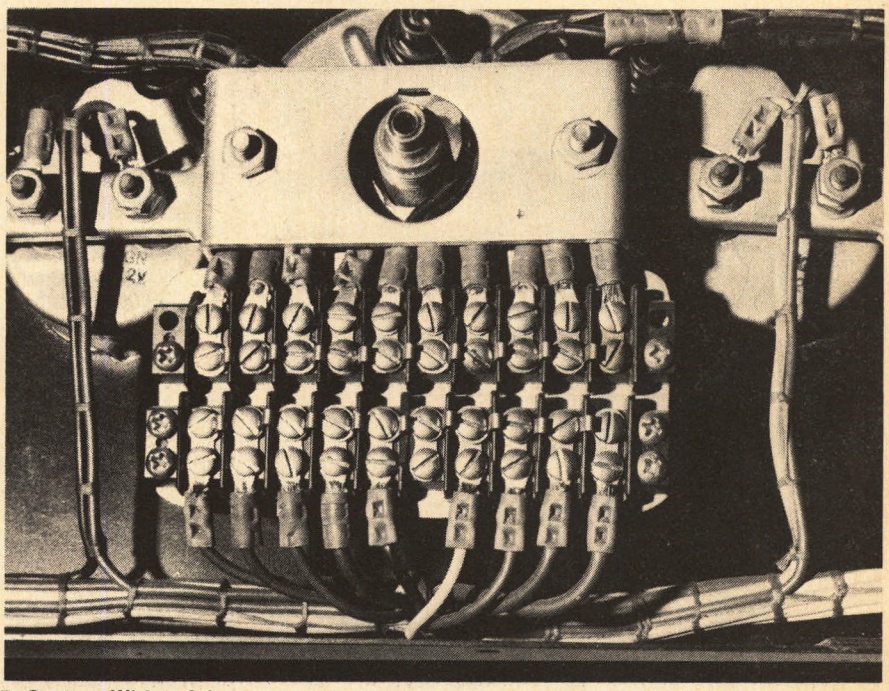
4. Adjusting Fuel Gauge

your own un-level driveway and a jack or two used to adjust the level of the car slightly to duplicate the bubble position obtained with the car on level ground.

The car should be positioned 25 ft. from a garage wall or an aiming screen improvised from a large piece of cardboard. The aiming screen should have one horizontal line and three vertical lines drawn upon it. The horizontal line can be laid out with the help of the carpenter's level and should be at the identical height above the ground as the center of the car's headlights. The center vertical line should be at the car's exact centerline. This can first be drawn at right angles to the horizontal line, if desired, and the aiming screen shifted from side to side until it is lined up with the center of the car's hood. You can "sight" through the rear window to do this. If there is no distinct center line in the hood, the center can be located with a tape measure, a small suction cup placed there for a "front sight" and a yardstick held straight up from the trunk lock for a "rear sight."

Two other vertical lines are then drawn which are the same distance apart as the centers of the car's headlights. These should be located equi-distant from the centerline, which will place them directly in front of the car's lights.

The adjustment on all Type-2 units is made with the headlights on low beam only. This will assure adequate illumination with the lights dimmed, and the built-in angle between the high and low beams will take care of the aiming for the "brights." Type-2 units, whether used on two- or four-headlight systems, have a "2" molded into the lens for identification. If the car has dual headlights, the high-beam-only #1 lights are adjusted separately. Three other prerequisites must be observed if you wish to do a good job: (1) Have the tires inflated to the correct pressures; (2) Have the car filled to capacity with gas, water, and oil—but no cargo or passengers; (3) Make sure all grille, fender, and headlight assembly bolts are tight.



5. Custom Wiring Job

AIMING TYPE-2 UNITS

On most cars you will have to remove the headlight trim ring to gain access to the adjusting screws. Some late-model cars, though, have access holes in the trim rings that allow you to stick a screwdriver through for adjustments.

Switch the lights on low beam. Cover the right headlight with your jacket, an old blanket, your mother-in-law, or anything else that's handy. Adjust the left light vertically until the top edge of its high-intensity zone is exactly on the horizontal line. The vertical adjustment screw is at the top of the sealed beam unit on most cars. When adjusting the aiming screws, move them first counterclockwise until the lights are definitely *out* of adjustment, and then gradually clockwise to bring them in. Otherwise the spring may not expand properly and will later allow the lamps to change their aim.

After positioning the light vertically, use the same procedure to move the beam horizontally until the left edge of the high-intensity zone is 3 ins. (2 ins. in some states) to the right of the vertical line in front of that headlight. The light's horizontal adjusting screw is located to one side of the sealed beam mounting. By moving the covering from the right headlight to the left, it will be possible to make the same adjustments to the right side. This is the end of the job for cars with single lights. Dual headlight installations must still have their #1 lamps aimed.

AIMING TYPE-1 UNITS

The actual work is done exactly as it was in aiming the #2 lamps, but the

beam is positioned differently on the screen. Cover the three lights not being adjusted. Aim the exposed high beam until the center of its "hot spot" is 2 ins. lower than the intersection of the horizontal line and the vertical line in front of that light. On station wagons and softly-sprung sedans the hot spot should be centered further below the horizontal line to compensate for vehicle loading differences. This measurement depends on your state's particular motor vehicle requirements.

If you have a car with single headlights that is equipped with the old 5000 series sealed beam unit (without the #2 on the lens), then they should be adjusted while on high beam only, according to the instructions given above for aiming #1 units (those with a single filament high beam).

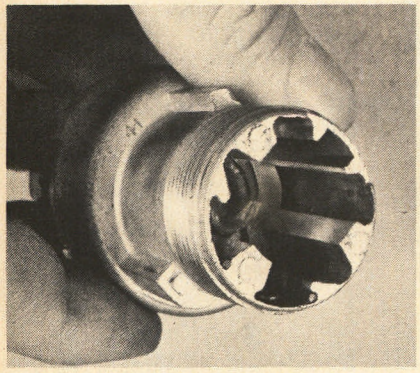
SOME OTHER LIGHTS

Burned-out taillights, instrument panel bulbs, and what have you, are usually fairly quick and easy to change. The average car has about 15 or 20 small lamps—not all of them the same size. When a small bulb stops functioning, you should take it out and check to see that the lamp itself is really to blame. Quite often, parking light and turn signal units will suffer the ravages of weather, water and roadside mud until the wires or sockets themselves finally succumb to corrosion and rot. If the bulb turns out to be OK, insert the probes of a test light into the socket (with the switch controlling the light turned on) and see if current is actually reaching the lamp. If it is, the trouble is probably nothing more than a coating of crud on the socket or bulb contacts. Scraping the terminal contacts on both the bulb and socket should do the trick. Poor ground contact could also be a factor, so don't forget to polish up the lug pins on the lamp base, and also the slots in the socket that they fit into. Check the ground between the socket and its holder, between the holder and the fender, and between the fender and the body. The electricity has to get back to the ground terminal of the battery. It can be stopped at any one of those points. We have fixed many an old car that was hopelessly rusted up by running a ground wire from the bulb sockets to the frame of the car. It's a lot easier than trying to get a ground through all that rusty sheetmetal.

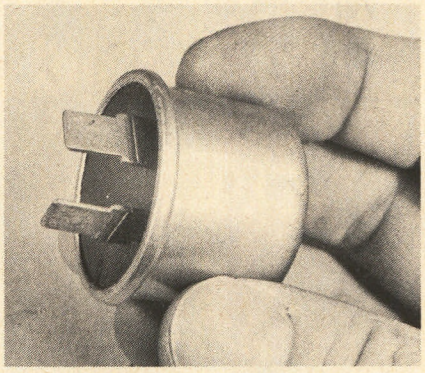
If no current is reaching the socket, a broken or shorted wire—or possibly a faulty switch—is at the bottom of it all. However, most switches operate more than one bulb, or at least something else besides the bulb. If the other components in the circuit are functioning properly, the trouble is not likely to be in the switch.

Every bulb has a number printed on its base, and when buying a replacement you should try to find a lamp having the identical number. Often the parts store will have a chart or booklet listing the bulbs used for particular applications in various makes and models of cars. Tell them what kind of car you drive, and which lamp has burned out, and they'll probably be able to fix you up.

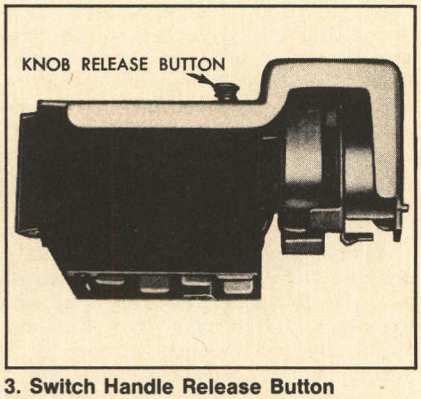
The lights on the outside of the car's body are pretty easy to work on, but some of those located behind the dashboard seem to have been put there by Houdini's ghost. Trying to get your hand up through the maze of wires and controls sometimes requires the agility of a serpent and the patience of a saint. These small instrument panel lamps are usually retained in sockets that can be taken out of the back of the instrument panel by turning them about ¼-turn counterclockwise and pulling them out. The sockets on a few cars simply press into holes in the back of the panel. Once the socket is out it can be pulled from



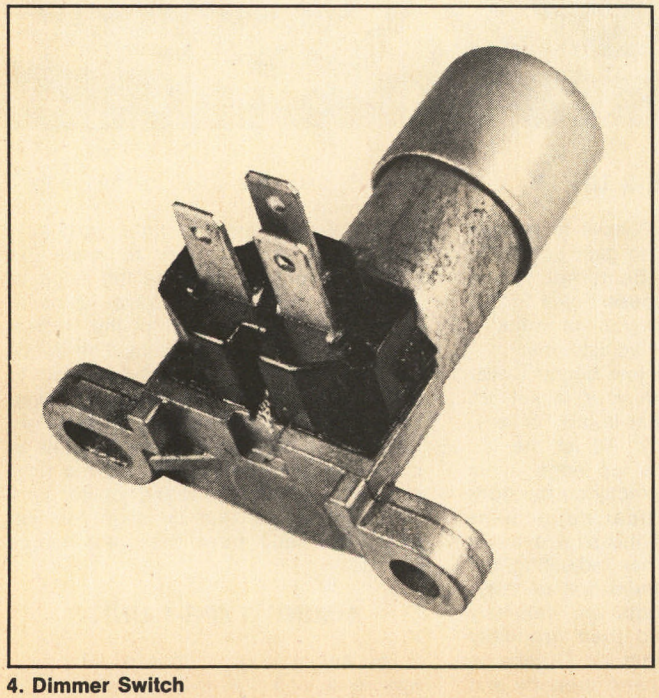
1. Ignition Switch Housing



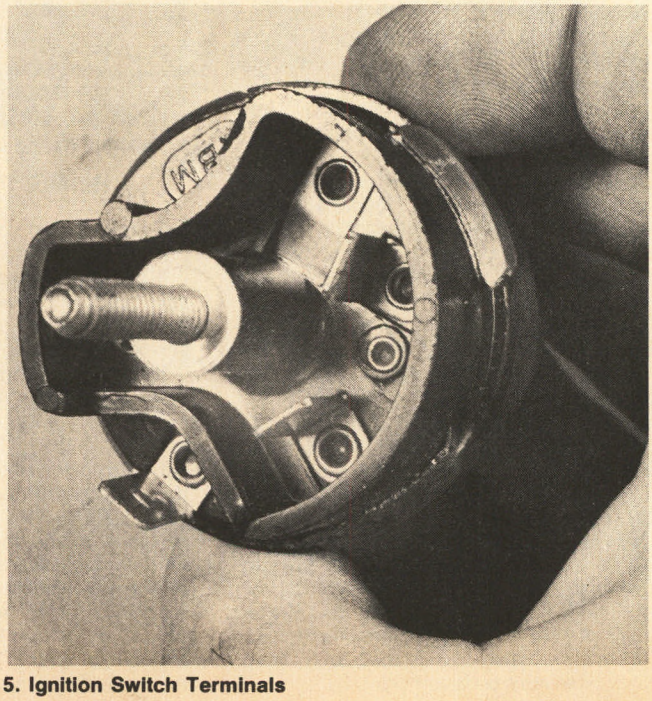
2. Flasher Unit



3. Switch Handle Release Button



4. Dimmer Switch



5. Ignition Switch Terminals

1. The switch end of ignition switch will accept your old lock, so you don't have to change keys if you replace the electrical part of switch.

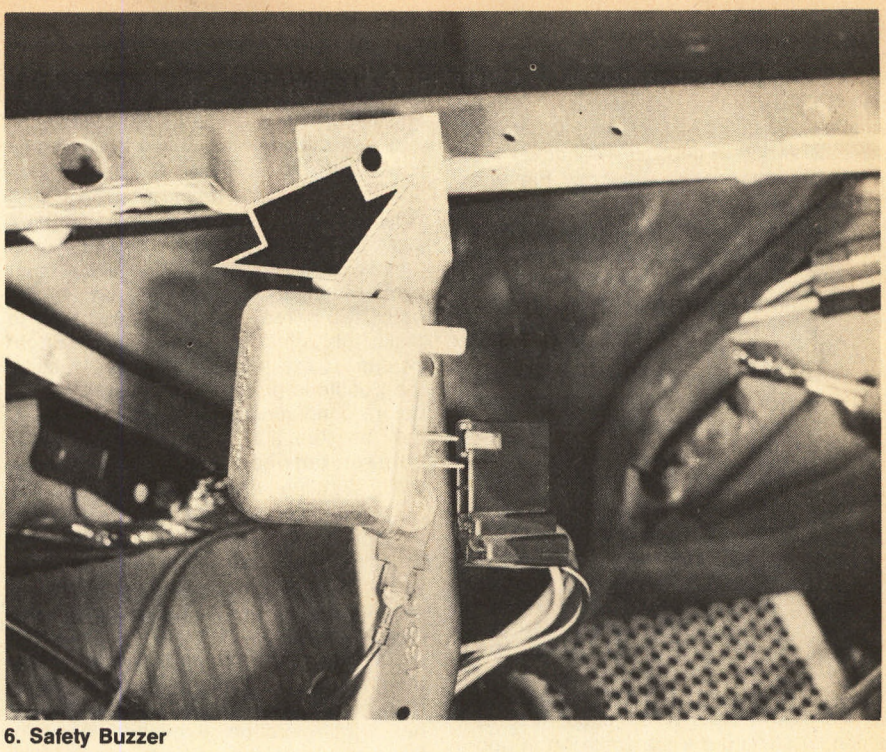
2. Flashers for most late-model cars are simple plug-in type. They come in many different electrical values, according to the number of bulbs on the car that are in flashing circuit.

3. The knob and shaft on a headlight switch are removable by pushing this button (arrow) on the switch.

4. Late-model dimmer switches are 1-piece units with plug-on terminals for the wiring. They can't be taken apart for servicing.

5. Center post at back of ignition switch is for accessories. The other terminals are shielded to prevent shorts, or "hot wiring."

6. If you've wondered where that obnoxious noise comes from when you open the door of a late-model car without first removing the ignition key . . . here's the culprit. Buzzer is usually buried in the most inaccessible place behind the dash to discourage disconnecting or removal.



6. Safety Buzzer

under the dash, the old bulb exchanged for a new one, and the socket reinstalled behind the instrument panel.

Taillights, backup lights, parking lights, and turn signals are generally serviced by removing the lens and trim ring. Most cars have from one to four screws holding the trim ring in place and, once these are taken out, the ring, lens, and gasket will come off to give access to the bulb. Actually, on some late-model cars—including nearly all Chevrolets—it is possible to replace the bulbs in the tail, stop, and backup lights from inside the trunk. These lights have sockets that can be pulled out in a way very similar to the bulb holders used on the back of the instrument panel—making the whole job easier.

Many of the bulbs used in rear-end lighting are "combination" types that have two filaments and serve as both a taillight and turn signal, or as a stoplight and taillight. For this reason it is imperative that the same type of bulb be used. Also, only by installing bulbs of the right specifications, can you be sure of getting the precise degree of brightness required for safety by the motor vehicle laws.

SWITCHES

If the bulbs are all OK, but your stoplights or backup lights *still* won't work, or dimming your headlights for an upcoming car sometimes makes them go *completely out* you've got switch troubles. Usually, the only cure is to put in a new switch.

In the case of light, heater, and windshield wiper switches that are mounted *through* the dash, it's necessary to take off the control knob before the faulty unit can be removed. In the majority of cases, a small set screw—often the "Allen" variety—must be taken from the underside of the knob before it will come off the shaft. Some controls may have knobs that are threaded onto the shaft and can simply be unscrewed, while others employ spring retainers that are freed by inserting a small wire into a hole in the bottom of the knob. As mentioned earlier, the knob and control shaft on some GM cars is taken out as a unit by pulling the control to the "ON" position and depressing an under-dash button located on the switch body to free it.

The ferrule nut that holds the switch in the dash often takes some pretty exotic shapes. A few are easy to grip with fingers or with common tools, but others are intended to be taken off with a special tool. It's usually better to improvise such a tool from wood or wire than to try "brute force" (such as a pair of pliers), which will only lead to unsightly scratches on the ferrule nut and dashboard. Once the switch is out of the dash, the wires can be disconnected and a new switch installed.

Whenever you change a switch, it's a good idea to label all wires so that they can be reinstalled in the correct positions. However, most late-model cars have plug-in connectors that preclude any possibility that the wires may become confused. These plugs also make the job much quicker and easier. As a further precaution, the battery ground cable should always be disconnected during the switch changing operation to prevent accidental shorts that could blow fuses, start fires, or run the battery down.

While nearly all switches are serviced as complete units only, there are a few which may be returned to useful service by simply tightening, adjusting or lubricating the switch or its linkage. Stoplight switches that are operated mechanically off the brake pedal can cause two kinds of easily-fixed trouble. Those found on older cars with brake pedals that pass through the floorboards are located *under* the car, and are therefore frequent victims of dirt and corrosion. These switches have a lever on them which contacts the brake pedal. The lever is spring loaded so that it will swing around in an arc as the brakes are applied and the pedal arm moves away from it. The switch lever is connected internally to a pair of electrical contacts which trigger the stoplights when they come together. If the switch lever's shaft becomes rusted or coated with dirt, it will no longer turn properly to follow the movement of the brake pedal arm. Result: no stoplights. In most cases a few drops of "Liquid Wrench," or a similar rust-dissolving oil, will free the frozen shaft. In bad cases the switch can be removed and washed in kerosene. After the Liquid Wrench or the kerosene bath, work the lever back and forth a few times and it should start to move freely once again. If it does not, the spring is probably broken and a new switch is required.

The stoplight switch used on late-model cars with "hanging" brake pedals is usually mounted under the dashboard just below the steering column on the brake pedal stop. Any trouble caused by these switches is more likely to result from vibration than corrosion. Should the retaining nut become loosened, it may allow the switch to move away from the pedal and the stoplights will remain permanently on. The switch must be remounted tightly in such a position that electrical contact is made when the brake pedal is depressed ⅜- to ⅝-in. from the fully released position, when the brake is "off."

Some stoplight switches are a friction fit in their bracket. To adjust them, push the switch toward the brake pedal with the pedal depressed. When the pedal is released, it will bottom the switch and push it back in the bracket to the right position.

The backup light switches fitted to most of the automatic and column-shift transmissions seldom cause trouble

since most are mounted on the steering column inside the car and out of the weather. If one goes bad, simply put the selector switch in neutral, disconnect the wires from the switch, unscrew the unit from the car, and install a new one. However, many cars with floor shifters have the backup light switch mounted on the side of the transmission *under* the car. These switches and their connections can take quite a beating from the weather, and may eventually cause trouble. Also, the small rod connecting the switch to the reverse gear bellcrank may become loose or rusty and fail to function at all.

To replace such a switch, the wiring is disconnected at an inline plug some distance from the switch itself. The cotter or wire clip is then removed at the point where the reverse lever rod is connected to the switch's control arm. Then you can remove the switch and its splash shield by taking out two screws. The bracket remains mounted on the transmission and should not be disturbed. After the new switch is in place, test its action by shifting the transmission in and out of reverse. The mounting holes on the switch are elongated, making it possible to adjust the switch's position for proper operation.

Like a well mannered rattlesnake, dimmer switches usually give some warning before they slip you the needle. You'd be well advised to investigate the cause of any malfunction at the first sign of trouble. Otherwise, you might suddenly find yourself driving 60 mph on a winding, tree-lined road without any headlights to show you the way.

Sometimes dimmer switch trouble is nothing more than a sticking plunger. Dirt and snow from your shoes may work its way into the switch and cause it to jam. Remove the switch and blow out any debris that's under the pedal cap and inject a few drops of penetrating oil into it. If the switch now works normally, you're back in business.

If the headlights refuse to go on and you suspect trouble in the dimmer switch, you can check the circuit with a jumper wire. By connecting the center wire leading to the switch to one of the other two wires, you should be able to make the lights operate on either bright or dim. If the jumper wire gets results, the trouble is probably in the switch. But, before condemning the dimmer switch itself, be sure that the trouble isn't poor contact between the wires and the switch terminal connections.

Most dimmer switches can be removed by folding back the upper left corner of the front floor mat and removing the wires and mounting screws from the switch assembly. Most late-model cars have a multi-wire plug connector which is simply pulled from the terminals. Place the multi-plug connector on the terminals of the new switch and check the headlight operation. If everything works OK, bolt in the new switch, replace the floor mat, and the job's done.

If the neutral safety switch found on cars with automatic transmissions goes bad it can stop you deader than Sitting Bull stopped Custer or, if it permits the engine to be started with the gear selector in the "drive" or "reverse" range, it might even convert your car into a lethal battering ram. As part of the circuit controlling the starting system, its failure will definitely be more than a slight inconvenience.

One type of neutral safety switch is screwed directly into the transmission, and the other mounts with two or three screws somewhere on the transmission selector linkage. It is commonly inside the console on cars with floor-mounted gear selectors, and somewhere on the steering column of others. Once the actual location is determined, the removal and replacement operation should be fairly obvious. In some cases the trouble is nothing more than dirty, burned, or grease-coated contacts. A little judicious cleaning will usually be all that's needed. But if there is obvious breakage, or signs of wear, get a new switch.

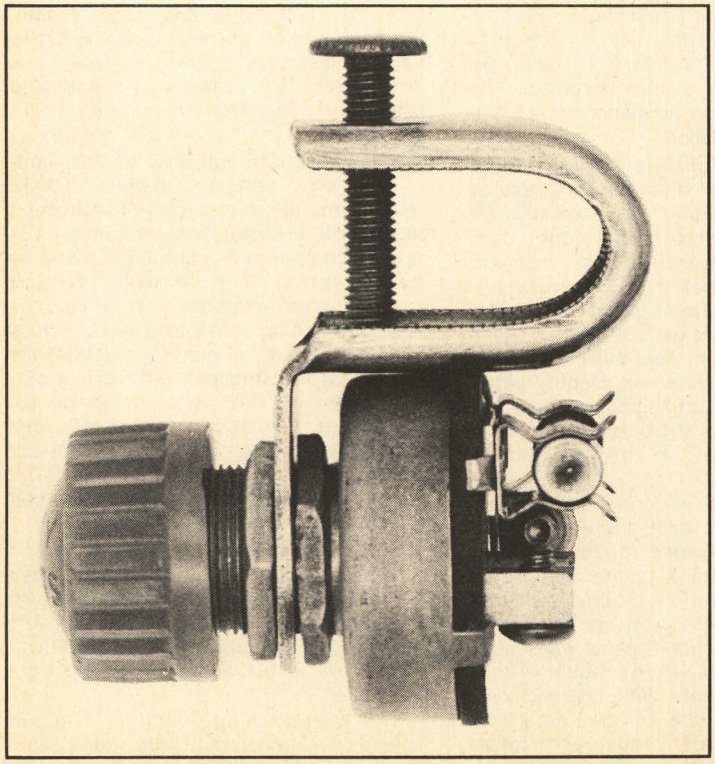
INSTRUMENTS

With the exception of the speedometer, and in a very few cases the water temperature and oil pressure gauges, all modern dashboard instruments are electrically operated. In recent years it has become common to limit standard instrument clusters to a speedometer and a fuel gauge with only indicator lights to warn the driver of flow oil pressure, engine overheating, and inadequate battery charging. Higher-priced cars and "sports" models usually hark back to the standard instrumentation of pre-1955 models and include an oil pressure gauge, temperature gauge, and ammeter. An electric tachometer and perhaps a clock may also be part of the instrument group.

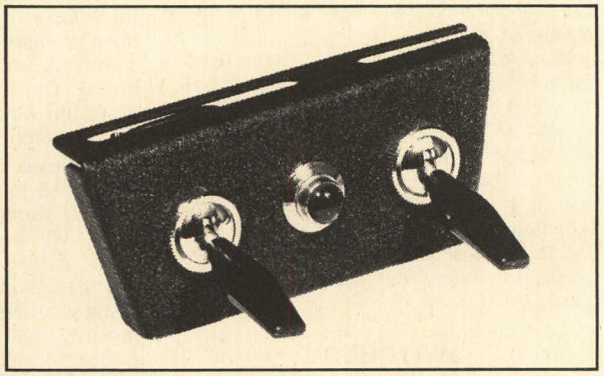
The lamp bulbs of the indicators ("idiot lights") are replaced in exactly the same way as other dashboard lights. There is no regular maintenance that needs to be performed on any of these instruments.

CLUSTER REMOVAL

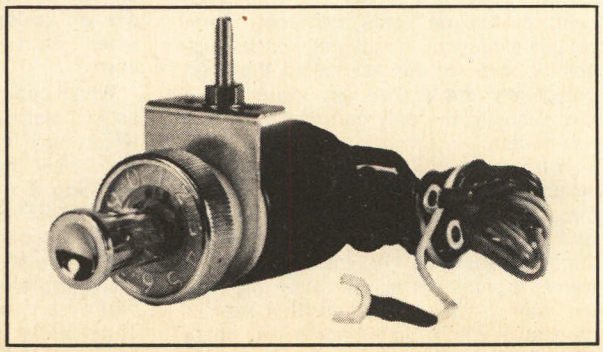
Many of the less elaborate instrument layouts can be serviced without taking the panel out of the car. However most



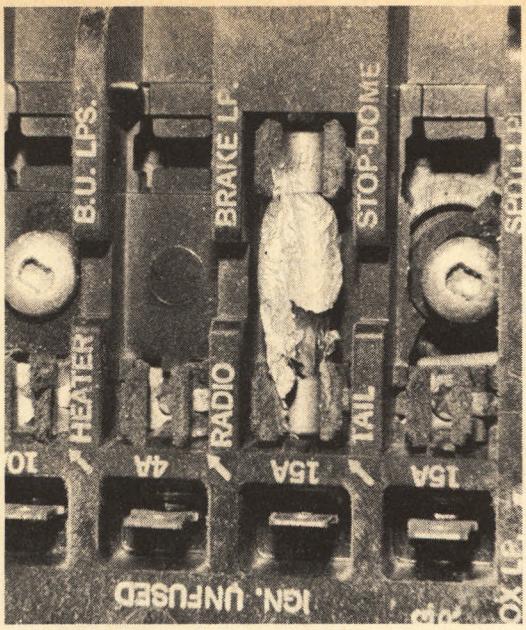
1. Fuse on Back of Switch



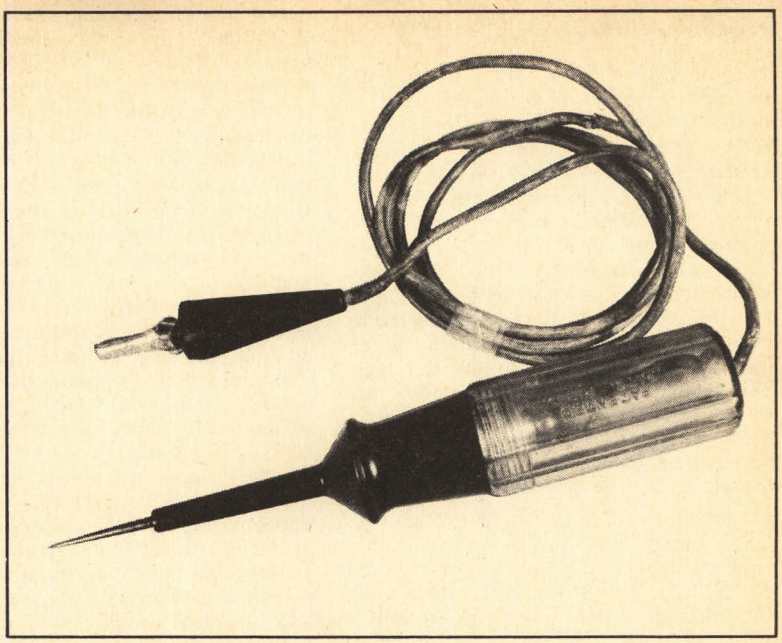
2. Bat Handle Switches



3. Keyless Switch



4. Tinfoil on Fuse



5. Non-Powered Test Light

1. Some switches have their own fuse right on the back, plus a mounting bracket for use under the edge of the instrument panel.

2. For accessory installations, bat handle toggle switches like these by Aris Sales Co. bolt easily under the dash and are available with one, two or three switches, with or without the indicator lights.

3. Keyless Key by Karset Co. not only helps prevent theft but may cut down on drunken driving, because a drunk can't work the combination.

4. Wrapping a blown fuse with foil to keep from blowing fuses is just asking for trouble, even fire. Better to track down what caused the first fuse to blow and correct it.

5. The old non-powered test light is extremely reliable. The light bulb is inside the handle and can easily be changed when it burns out. To use, ground the clip, then touch the point to any terminal to see if it's hot.

of the cars that have "extra" instruments installed as "options" must have the panel removed before you can get at the gauges. The battery ground cable must in every case be disconnected when the instrument cluster is being taken out to avoid electrical damage. On most cars it is also necessary to remove the steering column housing or in some instances to "drop" the column assembly from its dash mounts. Since in many cases the instrument cluster will slide along the steering column jacket as it is removed, the jacket should be wrapped with masking tape to protect it from scratches.

Before loosening the cluster from the dashboard, the retaining collar holding the speedometer cable must be unscrewed and the cable slipped out of its socket in the speedometer head. If there is an oil pressure line (as on many GM "sports" models), this must also be taken off. The screws holding the instrument cluster in place may then be removed. There are generally from four to six of these located around the cluster, Phillips-type screws being commonly used to retain it.

Once the retaining screws are out, the cluster can be pulled out of the dashboard. When there is adequate working space between the cluster and the dash, the remaining wires can be unplugged or disconnected if it is desired that the instrument cluster be removed completely from the car. However, if the car has console-mounted instruments, it may be necessary to dismount the main instrument cluster before the front of the console can be lifted off.

Since many instrument panels are now being made of plastic, there may also be one or more ground straps to provide ground polarity to the instruments. When replacing the panel, be very sure to reinstall these properly to secure the best possible electrical contact and assure a good ground.

FUEL GAUGE AND VOLTAGE LIMITER

All modern fuel gauges are electrically operated and are actually nothing more than simple devices capable of measuring the amount of voltage transmitted from a sending unit located in the car's fuel tank. There is also a voltage-limiting relay in the circuit to prevent inaccurate readings due to voltage changes initiated outside the gas gauge's own wiring system. On some automobiles the voltage limiter is an integral part of the fuel gauge itself, but it may also be a separate behind-the-dash unit. In most cars equipped with electric oil pressure and water temperature gauges, these units are connected to the same voltage limiter as the fuel gauge. In rare cases, each gauge may have its own built-in limiting device.

A fuel gauge that shows a "full" tank whenever the ignition is switched on is probably not "stuck" as it may seem to be. There are three other far more likely electrical causes for this malfunction. The most common is an improperly grounded gauge or instrument cluster. If the cluster is not grounded, all other electrical gauges will also be against the peg at the high end of their scale. The ammeter, however, will not be affected, and an electric tachometer that is not properly grounded will read a constant "zero." The only necessary repair in such cases is to restore good ground contact to the instruments or to the panel. In the case of a plastic panel, there is often only one ground connection or ground strap for all instruments. The individual units are then grounded to one another. This is why all gauges may be affected by a poor ground potential. If the car has a metal panel, however, the problem may affect only the fuel gauge.

You can test for faulty ground connections simply by connecting a jumper wire to some grounded point on the car and touching its opposite end to the back of the high-reading instrument (or zero-reading instrument in the case of the tachometer). If it then reads normally, you've found the trouble.

A faulty voltage limiter can also cause the gauge(s) to read high or low—either at one peg or the other, or at any "odd" place in between. If the needles occasionally make sudden "surges" to higher-than-normal readings, this is also the result of a faulty voltage limiter.

A quick check of the instrument voltage limiter can be made by connecting one lead of a test light to the temperature-sending unit on the engine and the other lead to ground. Leave the instrument wire attached to the sending unit also and have the ignition switch turned on. A flashing lamp indicates that the limiter is working. A voltmeter can also be used to make this test. The reading should fluctuate between 0 and 7 volts on a car with a 12-volt electrical system.

If the car has only a fuel gauge, the limiter can still be tested, but it will probably require that the instrument cluster be removed from the dashboard. The limiter is tested by connecting a jumper wire from the "hot" post of the car's battery to the input (battery) terminal on the limiter. (Or fuel gauge, if the limiter is an

integral part of it.) Another jumper is connected from the grounded battery post to the case of the limiter or gauge. A test light—or the correct polarity lead of a voltmeter—should also be connected to the battery's grounded pole, and the remaining voltmeter or test light lead touched to the limiter's input terminal. A full 12-volt reading should be shown or, in the case of a test light, the bulb should burn brightly. The test lead must then be moved from the input terminal to the terminal that leads to the gauges. There should be a fluctuating reading of from 0 to 7 volts, or a flashing test light. If not, the limiter (or gauge-limiter combination) is defective. It should be replaced.

Another possible cause of a constant "full" reading is a short in the wire coming from the tank. If the wire proves to be OK, the gauge well grounded, and the voltage limiter operating properly, any trouble that exists must be in either the gauge mechanism itself or in the tank's sending unit.

The next item to check is the proper grounding of the sending unit. Clean away a small area on the fuel tank and another on the top of the sender. (Its location on the fuel tank can be determined by inspecting the tank to find the gauge wire's connecting point.) Attach a jumper wire to a good ground on the car's body and touch the other end to the clean spot on the fuel tank. If the gauge reads normally, the trouble is a poorly grounded tank. If the gauge still does not read accurately, touch the jumper to the clean spot on the sending unit. A normal reading here indicates poor ground contact between the tank and the sending unit. Should the reading still be "off," the trouble is either in the gauge or in the sending unit mechanism.

The best way to make further tests is with the help of an extra sending unit. By doing this, you can avoid going to the trouble of needlessly removing the car's sending unit from the gas tank. The extra sending unit can be a junkyard cheapie and does not even have to be from the same model car as yours. It must, however, be in good working condition. Once you've obtained the extra sending unit you can wire it to the car's gauge by grounding it to the vehicle's body with a jumper wire and attaching the gauge's lead wire to the test unit's terminal rather than to the terminal on the sender in the car. Turn the ignition switch to "on" and move the float of the sending unit up and down. The needle on the instrument panel should traverse the full range from *"empty"* to *"full."* There should be no sticking or jerkiness in its movement. If the gauge does not work properly, it will have to be replaced. If it *does* work properly, it means you'll have to work on the sending unit in your car.

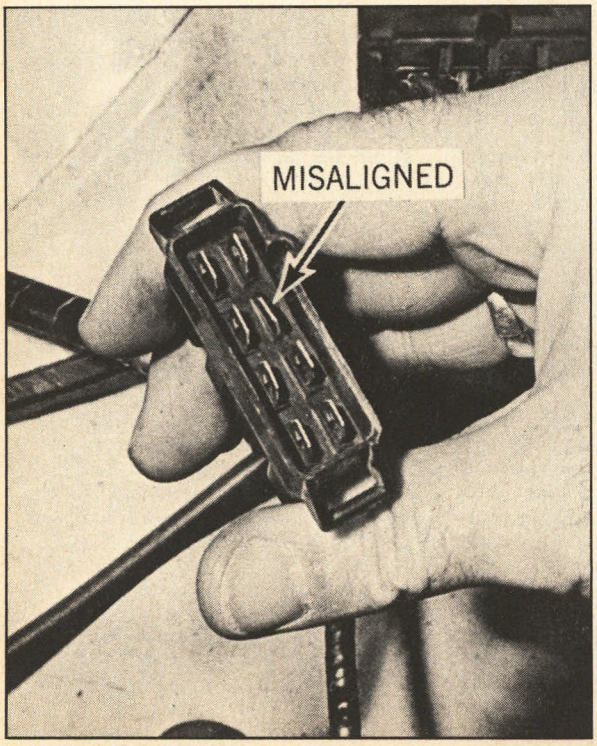
It may be necessary to take the tank out of the car on some makes, but it's usually possible to remove the sending unit with the tank still in the car. *However, be sure you disconnect the battery cables first.* One little spark is all it would take to turn you and your car into a king-size torch.

Clean all undercoating, dirt and corrosion from the area around the sending unit and take out the cap screws or locking ring holding it in place. Locking rings are designed to be removed with a special wrench, but we have found that a large screwdriver laid across the ring will get enough bite to remove it. Remove the sending unit from the tank, and clean away all dirt and corrosion from its electrical connections and components. Working a safe distance from the open gas tank, connect the sending unit to the gauge wire and to ground as you did with the test sender. Use a couple of long jumper wires for this. If the sending unit now operates the gauge normally, your cleanup did the trick. If not, you'll need a new unit. Before putting the unit back, you should get a new gasket from your car dealer. Sealer or gasket cement is unnecessary. Just put it on dry.

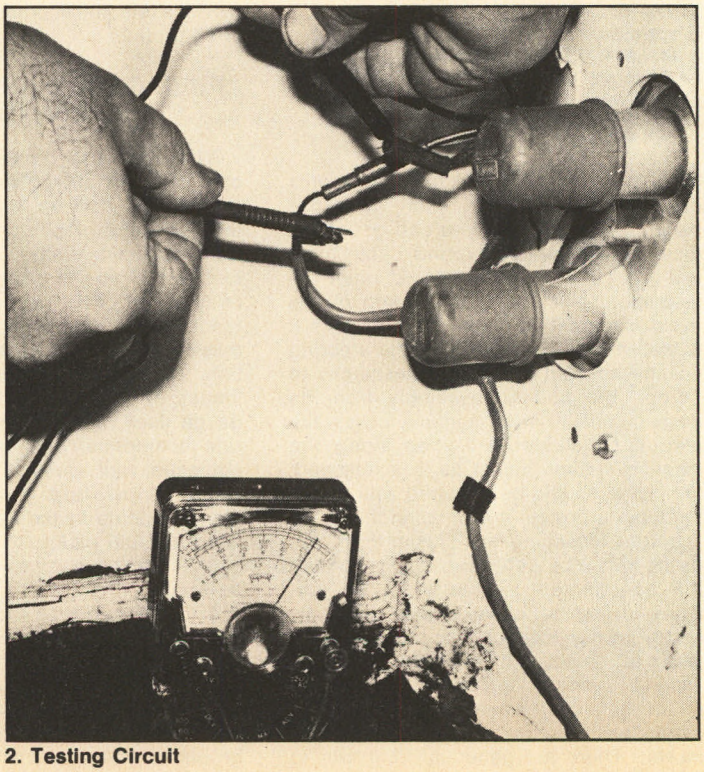
TEMPERATURE AND OIL PRESSURE GAUGES

If your car should be equipped with electrically-operated temperature and oil pressure gauges, the tests used on the fuel gauge should work on these as well. If their needles move to the maximum reading when the ignition is switched on, the trouble is poor ground contact, a faulty voltage limiter, or a shorted lead wire. A "zero" reading means broken or dirty electrical connections, a faulty voltage limiter, or a defective sending unit or gauge. If the gauge can be made to go from "zero" to "maximum" by disconnecting the wire from the sending unit and grounding it, the trouble is in the sending unit, which must therefore be inspected and cleaned or replaced as an assembly.

Electric gauges commonly used in modern cars work on the thermal principle. That is, voltage differences produce temperature changes in the gauge's mechanism which in turn move the needle. If the instrument panel loses its ground contact, the needles on the fuel, temperature, and oil pressure gauges may be forced far above their normal maximum dial readings. This may result in the permanent destruction of their accuracy. When a good ground is restored, the gauges will operate normally once again but at somewhat higher lev-



1. Multiple Connector



2. Testing Circuit

BELDEN AUTOMOTIVE PRIMARY WIRING SAFETY GUIDE

Total Approx. Circuit Amperes		Total Circuit Watts		Total Candle Power		Wire Gauge (For Length in Feet)											
6V	12V	6V	12V	6V	12V	3'	5'	7'	10'	15'	20'	25'	30'	40'	50'	75'	100'
0.5	1.0	3	12	3	6	18	18	18	18	18	18	18	18	18	18	18	18
0.75	1.5			5	10	18	18	18	18	18	18	18	18	18	18	18	18
1.0	2	6	24	8	16	18	18	18	18	18	18	18	18	18	18	16	16
1.5	3			12	24	18	18	18	18	18	18	18	18	18	18	14	14
2.0	4	12	48	15	30	18	18	18	18	18	18	18	18	16	16	12	12
2.5	5			20	40	18	18	18	18	18	18	18	18	16	14	12	12
3.0	6	18	72	25	50	18	18	18	18	18	18	16	16	16	14	12	10
3.5	7			30	60	18	18	18	18	18	18	16	16	14	14	10	10
4.0	8	24	96	35	70	18	18	18	18	18	16	16	16	14	12	10	10
5.0	10	30	120	40	80	18	18	18	18	16	16	16	14	12	12	10	10
5.5	11			45	90	18	18	18	18	16	16	14	14	12	12	10	8
6.0	12	36	144	50	100	18	18	18	18	16	16	14	14	12	12	10	8
7.5	15			60	120	18	18	18	18	14	14	12	12	12	10	8	8
9.0	18	54	216	70	140	18	18	16	16	14	14	12	12	10	10	8	8
10	20	60	240	80	160	18	18	16	16	14	12	10	10	10	10	8	6
11	22	66	264	90	180	18	18	16	16	12	12	10	10	10	8	6	6
12	24	72	288	100	200	*18	18	16	16	12	12	10	10	10	8	6	6
15	30					18	16	16	14	10	10	10	10	10	6	4	4
20	40					18	16	14	12	10	10	8	8	6	6	4	2
25	50					16	14	12	12	10	10	8	8	6	6	2	2
50	100					12	12	10	10	6	6	4	4	4	2	1	0
75	150					10	10	8	8	4	4	2	2	2	1	00	00
100	200					10	8	8	6	4	4	2	2	1	0	4/0	4/0

*18 AWG indicated above this line could be 20 AWG electrically—18 AWG is recommended for mechanical strength.

3. Wiring Guide

1. Multiple connectors such as used on most cars today at the firewall are excellent places to make tests with a voltmeter in tracing wiring problems. The terminals themselves should be checked for any damage or corrosion as possible trouble-spots.

2. A voltmeter can be very useful for detection of any shorts or open circuits in the wiring. Test probes are inserted into a separate inline connecter here to see if the circuit is on or off, not to measure it.

3. This Belden wiring guide is a handy item to have when doing wiring and trying to figure out what gauge wire to use for a certain length.

els. If it's possible to "get inside" the individual gauges, you can usually restore their accuracy with a little judicious bending or—in the case of most imported cars—some careful fiddling with the calibration adjustments. If the gauges are "sealed units," then they'll have to be replaced.

Water temperature gauges that are connected by a long copper tube to a fitting in the engine's cylinder head are thermo-mechanical rather than electrical in operation. When the copper tube is broken, the gas or liquid it contains is lost and a new gauge—complete with tube and sensor—must be obtained. So long as their tube is not bent, dented or broken, these instruments are quite accurate and free of service problems.

Oil pressure gauges that actually have an oil line leading to them can eventually be rendered inoperative if the tube becomes plugged with sludge. It is usually possible to unplug these by simply disconnecting both ends of the line and blowing it out with compressed air.

AMMETERS

Ammeters are always made as sealed assemblies and cannot be repaired. Trouble—though seldom encountered on ammeters—is always shown by a constant zero reading. An operating ammeter will always show a discharge when the headlights are switched on and the engine is not running. Since ammeter failures are so rare, it is always advisable to check the wiring thoroughly before condemning or replacing the instrument itself.

SPEEDOMETER SERVICING

The speedometer head should be serviced only by an authorized agent. If you try to save a few bucks by working on it yourself, you'll probably end up paying twice the amount in fines for speeding. However, you can reduce the labor costs somewhat by removing and installing the unit yourself.

On some cars—including practically every import—the speedometer can be removed from the back of the dash. This is done by unscrewing the speedometer cable, disconnecting the illuminating light(s) and taking out the two screws holding the speedometer onto the rear of the panel. Most late-model American cars must have the instrument cluster taken out of the dash as described earlier, and the speedometer subsequently dismounted from the removed cluster.

With all the furor about the difficulty of repairing cars, many of the car makers are now designing speedometers and other instruments that come out the front of the dash, after a small piece of trim is removed. Look for these easy removal jobs before you start crawling under the instrument panel with a flashlight.

If the speedometer makes weird noises—particularly in winter—or if the needle jerks back and forth instead of producing a steady reading, the trouble is probably that the speedometer cable needs lubrication. A broken cable will prevent the speedometer (and odometer) from registering at all.

To remove the speedometer cable for lubrication or replacement, it is first disconnected from the back of the speedometer as outlined earlier. Once the retaining ring is unscrewed or unlatched from the speedometer it should be possible to pull the cable's flexible conduit from behind the instrument so that the cable itself may be withdrawn from it. If the cable is broken it may be necessary to remove the retaining ring that holds the conduit to the transmission housing and take the lower half of the cable out from that end. On some Oldsmobiles the speedometer is driven off the left front wheel. By removing the hub cap, the cable can be withdrawn from the center of the wheel spindle.

Use only an approved speedometer cable lubricant. Ordinary grease will become stiff in cold weather and liquify in summer. Apply the lubricant to only the first ¾ of the cable as you reinsert it into the conduit. Enough grease will rub off in the first part of the conduit to lubricate the remainder of the cable. When the cable reaches the transmission, it is

often necessary to rotate it several times before it engages the recess in the transmission's speedometer drive gear. Once the cable is in place the conduit should be reattached to the speedometer head and the car road tested to check its operation.

INDICATOR LIGHTS

When the ignition is switched to the "on" position, the oil, temperature, and generator lights should come on. If one fails to do so, the bulb and its connections should be checked to locate the trouble. If the generator light stays on after the engine is started, the charging system and the indicator light circuit should be checked.

A temperature indicator that continues to report a "cold" engine even after the car has been driven for several miles, or indicates a "hot" engine immediately after starting, probably has either a defective sending unit or a shorted wire between the sending unit and the indicator light.

Oil pressure indicators that come on and stay on while the engine is running should always be ample reason for turning off the engine and leaving it off until the trouble is pinpointed. Start by checking the oil level. If it's OK, the trouble may be only a dirty sending unit—or more serious, a defective lubrication system. Take the sending unit out and examine it. If the opening in the end is clogged with sludge, clean it and reinstall the unit on the engine. Start the engine briefly. If the light goes out, fine. If not, try a new sending unit. If it does not work, start checking the lubrication system.

Faulty sending units that fail to switch on the indicator light when the ignition is turned on can be spotted by taking the wire from their terminal and grounding it. If the lamp lights, try cleaning the sending unit. If it still does not function properly, replace it.

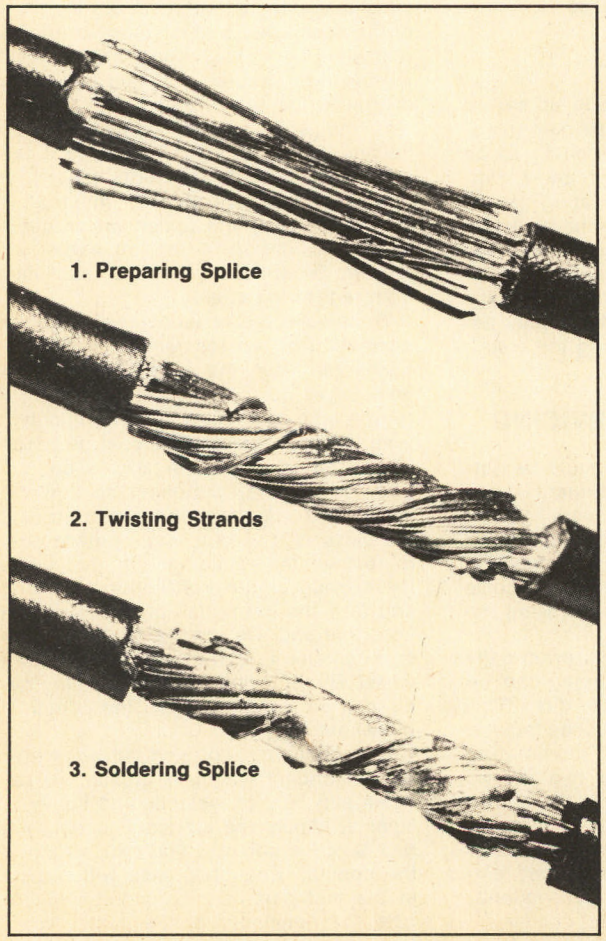
TACHOMETERS

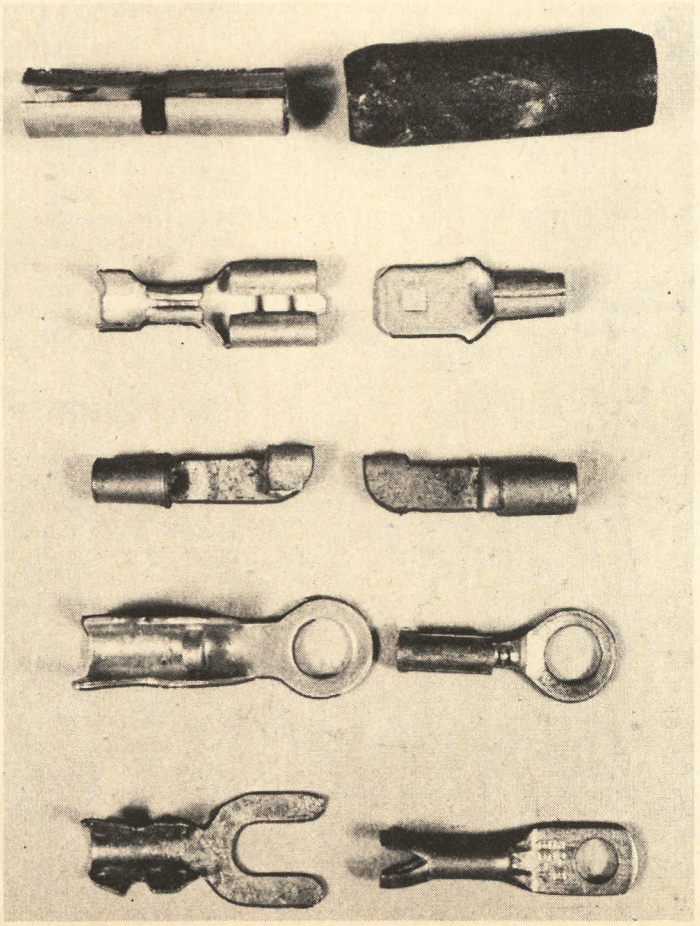
Cable-driven tachometers are not used on American cars except Corvette and some Chevys that use Corvette distributors. In actual practice their cables are serviced and lubricated exactly as speedometer cables are, and again, as in the case of the speedometer, actual repair of the instrument itself should be trusted only to authorized service agencies. The "factory-option" tachometers commonly installed on U.S. cars are serviced only as complete units—which means if yours goes bad you'll have to buy a new one. However, those sold as add-on accessories—providing they are a well known and reputable brand—can usually be repaired by the maker. Their addresses can often be found by checking the ads in the better-known motoring magazines.

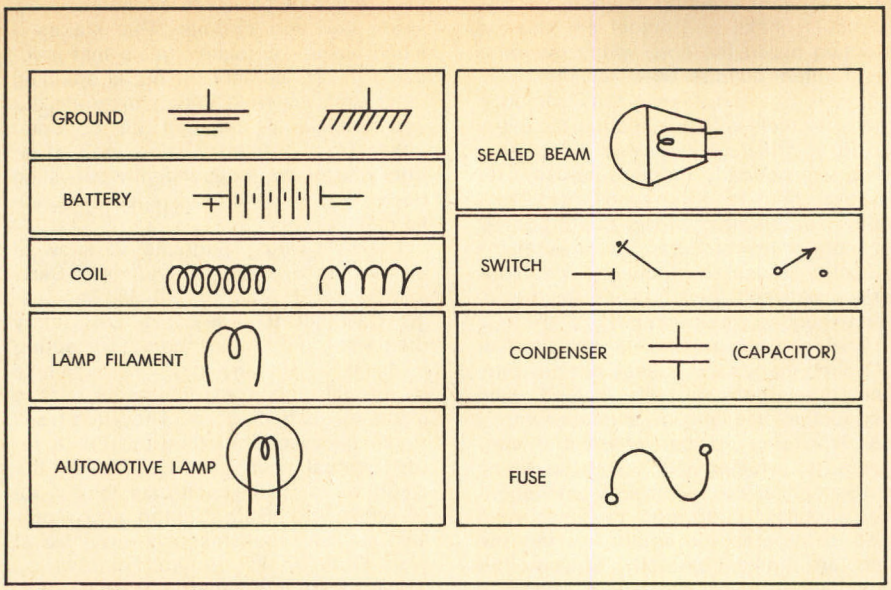
Probably the most common tachometer failures are those traceable to poor connections. In some cases the tachometer's only ground contact is provided by a wire serving the instrument's dial-illuminating light. If its socket does not fit tightly, there may not be adequate contact. Poor ground potential is always the first thing to check for when an electric tachometer fails to operate. The actual test is made by touching a grounded jumper wire to the tachometer housing while the engine is running. If the tachometer proves to be properly grounded, its connections with the ignition switch, coil or distributor (depending on the car) should then be inspected for poor contact and repaired if found to be the problem.

CUSTOM GAUGES

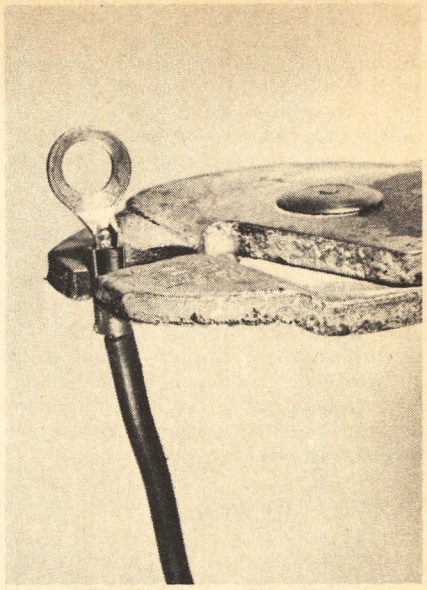
Most custom gauge installations consist of an oil pressure and ammeter duo to replace the idiot lights. The oil pressure gauge is easy to hook up, with its plastic tube and brass fittings. The usual place for attaching the tube is at the sending unit for the idiot light. A surprising number of the ammeters in dual installations are never hooked up, because the wiring is difficult to figure out. The ammeter should be spliced or connected into the wire that conducts charging current to the battery. If the ammeter is going to read correctly, the electrical load of the car (everything electrical except the starter) must be connected to the same side of the ammeter that the generator connects. On a generator car, the connection can usually be made at the




4. Solderless Terminals



5. Wiring Diagram Symbols



6. Crimping Solderless Terminal

1. Whether starting from scratch or just doing a repair, making good splices is important to trouble-free service. First step is to "skin" the wires. Then intersperse the strand tightly as shown here.

2. Second step in making a good splice is to twist the joined strands one or two complete turns.

3. Solder is applied from the tip of a hot iron so that it flows into twisted strands. Remove iron as soon as possible to avoid melting the insulation. Splice is then taped.

4. If you don't have access to a soldering gun or electrical outlet, then neat, simple solderless terminals like these are for you. They come in sizes for every gauge wire and type of connection desired.

5. These are some of the symbols used in wiring diagrams and what they stand for. Note the six cells in the battery, indicating it is a 12-volt. A 6-volt battery would have only three cells indicated.

6. Special pliers are used to crimp solderless terminals onto the wires.

starter solenoid. Alternators may require some extra wires to make the ammeter work right. Before buying an accessory ammeter, take the instructions out of the box and make sure you can understand the hookup. If the instructions are poorly written (as many are), then you'd better find a good automotive electrician.

Some of the more elaborate hot rod and custom car dashboards will sport such extras as a voltmeter, differential temperature, transmission temperature, head temperature and inside-outside air temperature gauges, an accelerometer and perhaps an altimeter. These should be installed and serviced according to the instructions and recommendations given by the instrument manufacturers.

TURN SIGNALS

The heart of any turn-signal system is the flasher with its regular beat. But it's a strange heart, because it stops working whenever a bulb burns out. Replace the bulb and the flasher will work again. The system is designed that way on purpose, so the driver will know he has a bulb burned out. The flasher depends on a certain amount of current flow to heat up a wire and cause the flasher points to separate. When the points separate, the circuit is broken, so the wire cools off and lets the points go together again. If a bulb is burned out, there will not be enough current flow to heat up the wire, so all the other bulbs on that side of the car will burn steadily, with no flasher action at all.

This type of flasher is designed with a specific load. It is made in different current-carrying capacities, according to the number of bulbs that need to be flashed on one side of the car. In the Tung-Sol brand, the first digit of the part number indicates the number of bulbs the flasher will operate on one side of the car (223 for two bulbs, or 322 for three bulbs). Signal-Stat doesn't have such an easy numbering system, but their specific-load flashers must still be selected for the number of bulbs on one side of the car.

Specific-load flashers can burn out easily, or their flashing rate will change if the wrong bulbs are installed in the turn signals. If you are having problems, check the flasher for the right part number, and look up the wattage of the bulbs you are using. Heavy-duty bulbs have a different current draw than standard bulbs, and that can goof up the flasher action, also. Heavy-duty specific-load flashers are better made, but they still must be selected according to the number of bulbs.

Variable-load flashers, sometimes called heavy-duty, are wired differently so they will flash anywhere from one to six bulbs at the same flashing rate. Hazard warning flashers are the variable-load type and can be used on any car as long as the total number of bulbs on both sides of the car does not exceed the design capacity (usually six). Of course, you could put a hazard warning flasher in your turn signal circuit and it would work fine. But then you would never know when a bulb burned out, because the flasher would keep right on working.

Because the hazard warning system is a second source of electricity feeding the same bulbs, some strange feedback situations can occur, but they are nothing to worry about. In some cars you can have a lot of fun with your technically-minded friends by leaving the ignition switch off, turning on the radio and the hazard warning switch, then stepping on the brake pedal and listening to the radio play a song about Ralph Nader. Another peculiarity is that the hazard flashers won't work if you step on the brake. This also means that they won't work if the stoplight switch is maladjusted, so it is on all the time.

In the regular turn-signal system, the stoplights are tied in so that the stoplight on the side being flashed is disconnected by the turn-signal switch. The stoplight has to be turned off because the turn signal uses the same bulb. If it wasn't turned off, stepping on the brake would cancel the turn signal on the flashing side.

Older cars with a single turn-signal indicator light on the instrument panel use a 3-prong flasher. The third prong is connected to the indicator. Inside the flasher, a special relay feeds current to the indicator, flashing it just like the signal lights. The special relay has to be there to prevent a feedback that would flash all the lights instead of just those on one side, because the indicator light is grounded directly to the body of the car. The "P" terminal on 3-prong flashers is the one that goes to the indicator light.

Later cars with a single indicator light use a 2-prong flasher. They get away with it because the indicator light is grounded through the front turn-signal light on the opposite side from the one that is flashing. This produces the strange situation wherein you notice that the indicator light doesn't work when you signal to one side, and the signals don't flash at all when you signal to the other side, but the indicator light burns steadily. The problem is a burned out front bulb on the side that doesn't flash.

If your car has two indicator lights,

both right and left systems are separate, which eliminates all the strange symptoms mentioned above.

Many cars have the flasher on the fuse block. If you can't find it, turn the signals on and then start hunting for the noise. If your hand touches the flasher, you can feel the vibration of the relay. Luckily, most late-model cars have plug-in flashers, so you can unplug and replace the flasher behind the instrument panel strictly by feel, without ever seeing where it plugs in. Be sure to take your wristwatch off when you grope behind the instrument panel. A metal watch can cause a bad short, and you could even get a burned wrist for your trouble.

REWIRING

When building a hot rod, or when doing extensive rewiring on any car, all electrical components should be in place before you start stringing wire. This will allow you to cut all wires accurately to length and bind them into neat bundles with electrical tape.

The ends of all wires should be fitted with appropriate terminals and connectors. Merely wrapping the bare wire around the terminal screw is neither a neat nor a professional way to build a car. Furthermore, such haphazard connections will almost always produce trouble later on. A wide variety of automotive terminals and connectors are readily available from parts stores.

WIRING DIAGRAMS

It is almost impossible to do an intelligent job of tracing electrical malfunctions without a wiring diagram for the particular make and model car you are working on. In the past, wiring diagrams were often difficult even for most mechanics to read, since they included many symbols which—although meaningful to engineers and trained electricians—were practically incomprehensible to the average person who reads them. Nowadays, automotive wiring plans consist of more-or-less accurate pictures of the actual electrical components with lines drawn between them to indicate the interconnecting wires and circuits.

Chevrolet began a new system in their '72 shop manuals that does not have the lines drawn between units. Instead, each connection has a code number, with a corresponding number where it is connected to another unit. Doing the wiring diagram this way eliminates the laborious process of drawing the lines (and also eliminates the foulups when the lines are drawn incorrectly). Maybe other manufacturers will adopt it, and the traditional wiring diagram with all the squiggly lines will disappear.

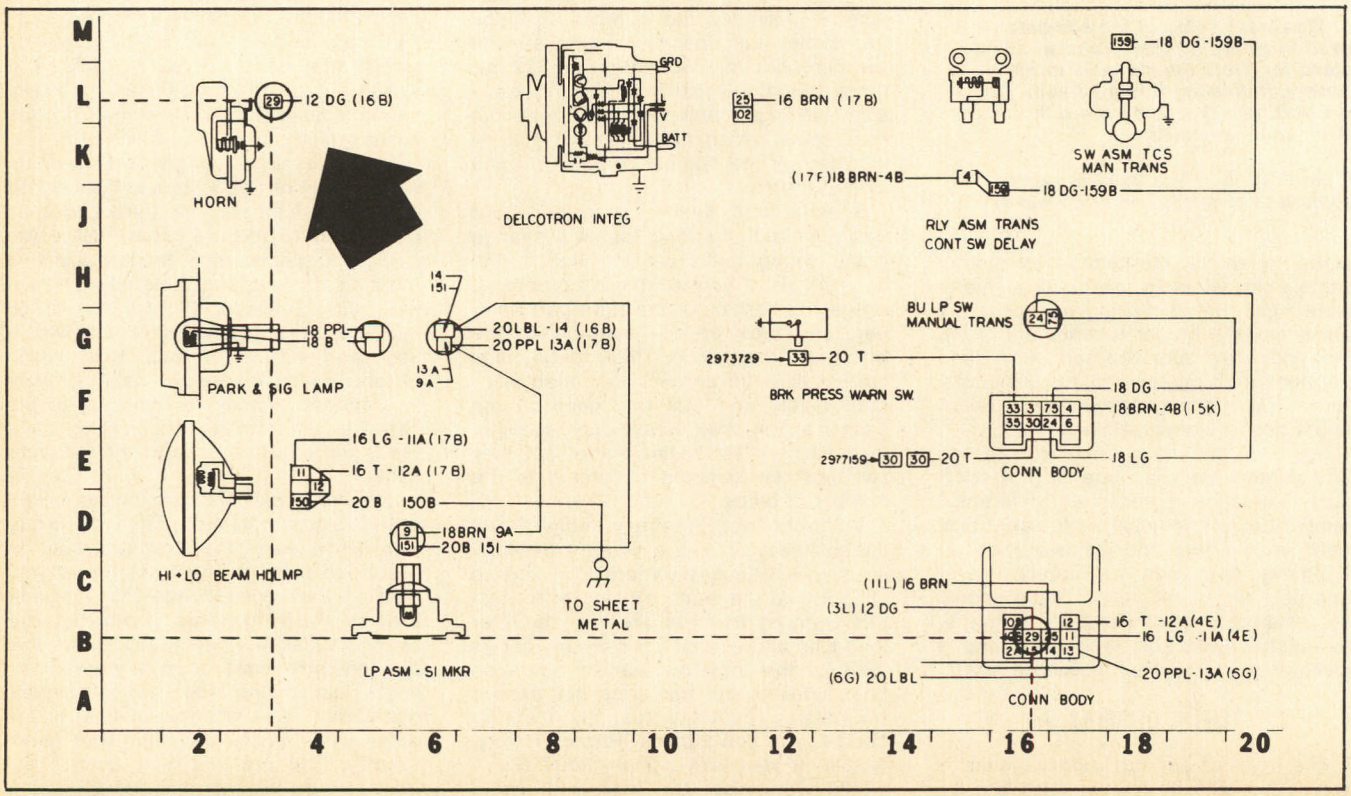
Each line or connection in most diagrams is labeled with a letter or number (or both) that indicates the color of the actual wire's insulation. If, for example, you wish to know which wire on the back of the ignition switch is connected to the ignition coil, you can quickly learn its color by checking on the diagram. If it indicates a *yellow* wire between these two units, you should be able to find it easily at the coil and on the ignition switch itself. Wires that are thought to have shorts or grounds can thus be located, disconnected at each end, and tested with a battery-operated test light or voltmeter to determine if trouble really exists.

Wiring diagrams also make it possible to determine what electrical components share common circuits. This makes it much easier to isolate trouble that is located in one component but is affecting other units as well. Wiring diagrams for your individual car can be obtained either from a factory shop manual or from one of the independently published books that deal with the repair of specific makes.

The best wiring diagrams we know of are put out by National Automotive Service, Dept. SP, P.O. Box 10465, San Diego, Calif. 92110. They take the factory diagrams and re-do them, correcting mistakes and rearranging the elements so that all units are in the same relative place in each diagram. They don't sell single diagrams, but they put out a repair manual each year that has all the diagrams for that year's cars, plus a lot of other info. Both Chilton and Motor also publish repair manuals, available at your local bookstore, but their wiring diagrams are in a separate book.

With the diagram's help—plus a few tools and some of the practical knowhow gained from this book—you should be able to keep your car's lights lit, horns tooting, and instruments registering accurately. What more could one ask for?

1. New type of wiring diagram used in '72 Chevrolet factory manuals has no lines between connections. Each connection can be identified with a number and letter. Take the horn, for instance (arrow). It is in circuit 29, which is the horn circuit. The number on its right shows: 12, the gauge of the wire; DG, dark green; and 16B, the location of the other end of the wire. Simple! This new system is designed to make it easier to read wiring diagrams.



1. New Chevy Wiring Diagram

Electrical Testing Procedures

Some definite plan or procedure must be followed in order to perform chassis electrical tests efficiently and quickly. With all the different types of electrical circuits found in an automobile, it is impossible to establish one set procedure which would apply in all cases. However, the following basic procedure will provide a systematic approach to any testing problem:

1) If the fault is in a single unit in a multiple-unit circuit, start the test at the unit.

2) If the fault affects all the units in a multiple-unit circuit, start the test at the point where the circuit gets its power.

As an example, let's apply this procedure to the lighting circuit. If only one bulb in the circuit will not operate, start checking at the light bulb and check back along each part of the circuit until the defective element is found. If all the lights in a circuit do not operate, start checking at the point where the power is first introduced into the circuit and check each connection in sequence.

One of the first steps to take in diagnosing any electrical circuit problem is to perform a visual inspection of the affected components and/or wiring circuit. The most common problems revealed by visual inspection are a defective connection or a damaged wire. A loose connection can cause intermittent operation of the circuit or cause the circuit to open. Corrosion can appear as high resistance or as an open circuit. A damaged wire is obvious by its sharp kinks or frayed insulation. The wires should be moved around by hand when you make this test. A wire may be rubbing against a sharp sheetmetal edge or on the point of a screw and cause the insulation to be cut or worn through to the wire. If the bare wire comes in contact with the sheetmetal or screw, the circuit will be "grounded."

The visual inspection should be made quickly—but cautiously—of exposed, easy-to-reach parts. A visual inspection does not mean a disassembly of body parts to check the wiring harness.

If a known good part functions properly when substituted for a part that is not operating, the part which was removed is defective. If the part is a fuse or a circuit breaker and the part fails repeatedly, look for an overloaded circuit or a grounded circuit.

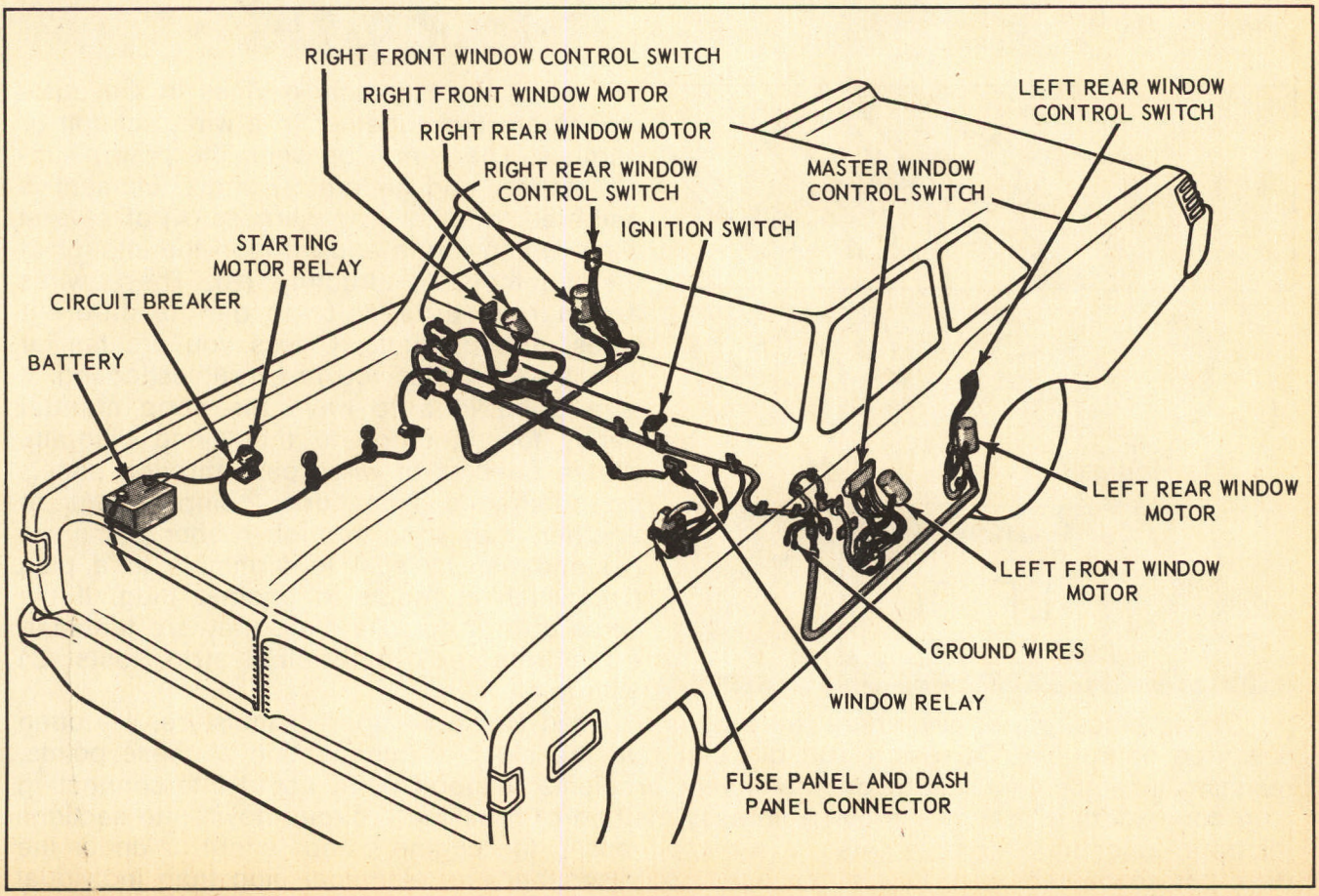
TEST FOR POWER: When a 12-volt test light lead is connected to a good ground and the other lead is connected to the circuit, there is power from the battery to the point where the test light is connected if the test lamp lights. If the test lamp does not light, there is no power in the circuit at the point being checked. This test can be made at any connection in the circuit.

A voltmeter, when properly connected between the circuit and a good ground, will show the voltage in the circuit at the point being tested. As with the test light, this is an indication of power in the circuit at this point. All switches in the circuit must be closed when you perform this test.

All electrical circuits must be complete from the source of power (battery) to the unit where the power is used, and back to the source of power again. A check at each connection in a circuit, starting at the battery, will locate an open circuit or will show that the circuit is complete.

A self-powered test light or ohmmeter, connected at any two points of a circuit with the power removed from the circuit, will show if the circuit between the two connections is open or complete. If the lamp does not light, the circuit is open. If the lamp lights, the circuit is complete.

In many cases when an electrical component stops operating, the trouble can be a blown fuse, and by replacing it with a good fuse the trouble may be eliminated. However, it can generally be assumed that something caused the fuse to blow other than just a bad fuse. If the second fuse blows soon after replacement, this is a sure sign of some other trouble.

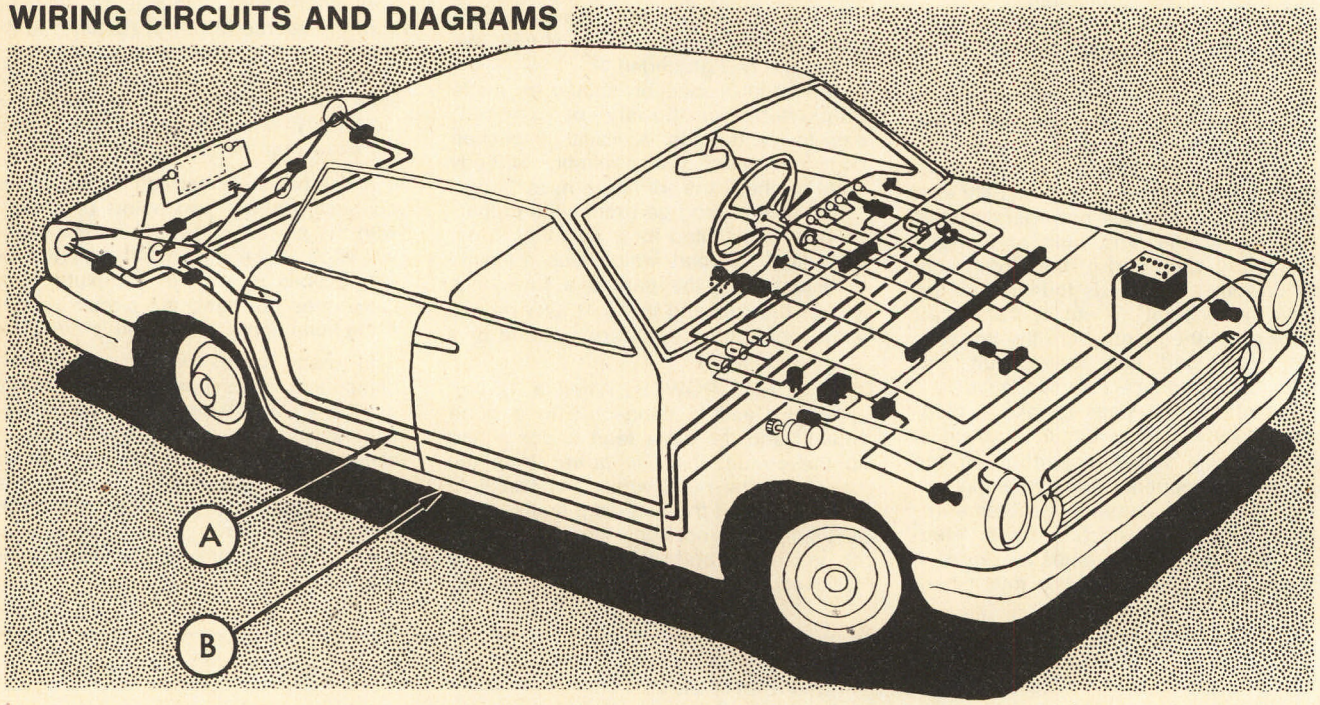


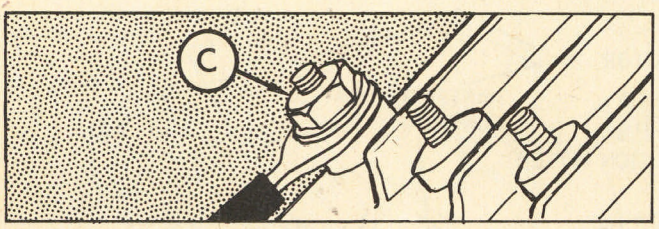
Power Window Circuit

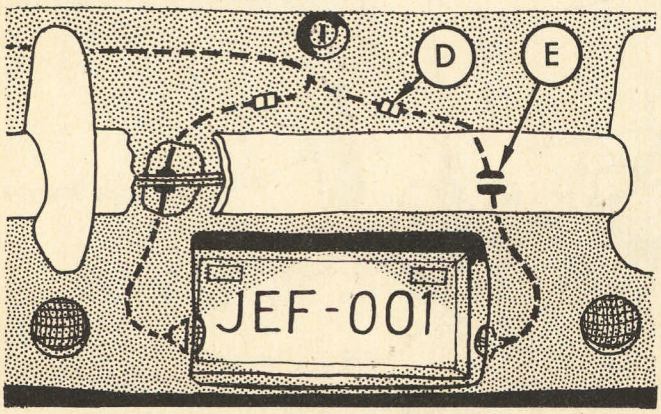
TROUBLESHOOTING ELECTRICAL ACCESSORIES

In this chapter we will again be using the multimeter as an electrical tester, as in the chapters on ignition and starters. Electrical equipment differs widely among the various types of automobiles, and it would be impossible to provide detailed electrical troubleshooting for each manufacturer's automobiles. We will give *generalized* instructions only for a variety of electrical equipment and rely on common sense troubleshooting techniques to allow the reader to find and fix his own electrical troubles. We will also show only a few *simple* electrical schematics. Schematics are hard to read for the average user and are very specialized for each individual automobile.

WIRING CIRCUITS AND DIAGRAMS





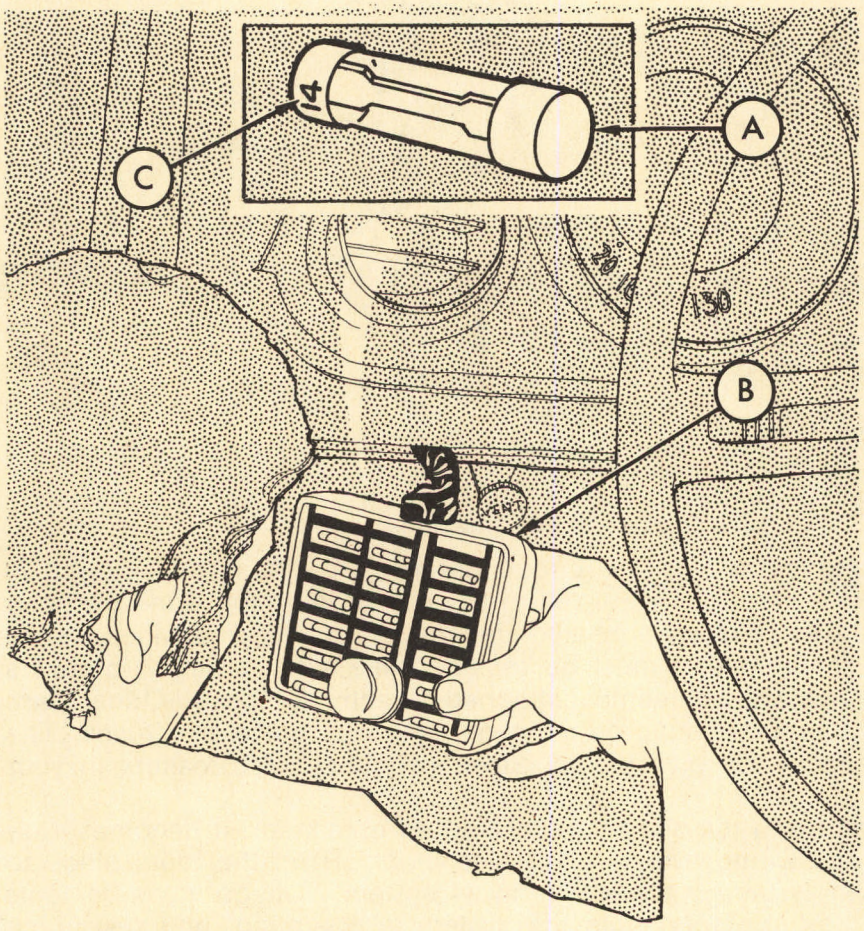


All of the electrical devices in the automobile are tied together in a wiring circuit or harness. The wiring between the power supply (battery and generator) and equipment is gathered together in a harness (A) of several wires which run in and through the interior of the automobile's structure (B). These wires are marked by a color to denote different wires and functions. Unless you are familar with the part that you are troubleshooting, it is a good idea to have the shop manual handy for reference to the wiring diagram. Where bundles of wires pass through panels or bulkheads from one compartment to another, they pass through rubber grommets (E) and usually split to terminate in a plug (D), which connects to another plug. If the wires do not go to a plug, they are terminated (connected) to terminal strip posts (C) with nuts.

These plugs, especially where the plug is exposed to the weather or moisture, are often a source of trouble. Corrosion and dirt can ruin the electrical connection at these points, resulting in equipment failure or intermittent problems. A good point about interconnecting plug connectors is that they provide an easy method of breaking a circuit down into sections for troubleshooting purposes. Also, if a component in the engine compartment or under the dash has to be removed, it is much easier to disconnect an electrical plug than individual wires.

CAUTION: USE CARE WHEN CONNECTING AND DISCONNECTING THESE PLUGS. THE PINS CAN EASILY BE DAMAGED.

As an example, suppose you are troubleshooting a headlight problem. Using the meter, you discover that when the switch is turned on, there is power to the headlight switch but not to the headlights themselves. A check of the headlights and their sockets turns up no visible problem. Your next step would be to see if the wiring from the switch to the lights passes through a plug connector. In fact, this switch usually does pass through a plug connector in the firewall. By disconnecting the plug connector you can then check for the presence of power at the plug connector. If there is power present, it means the trouble is between the plug connector and the headlights. If not, the trouble is between the plug connector and the switch. You have simplified the problem by checking for power at a halfway point in the wiring harness.



The heart of the electrical system is the fusebox or fuse panel (B). This is usually found under the dashboard, sometimes mounted on the inside of the firewall. The fuses for the various circuits are clipped into compartments, which are lettered to provide identification.

The fuse (A) is a protective device which consists of a small glass tube capped at each end with a metal tip. Inside the glass is a fine wire or metal strip connected to the metal tips. This fine wire or metal strip is designed to allow the amount of current required for the circuit to flow through it without a hitch, but it will rapidly overheat and melt in two if the current goes above its recommended value. Some fuses do not have a clear glass tube, and these must be checked with a meter to determine if they are good.

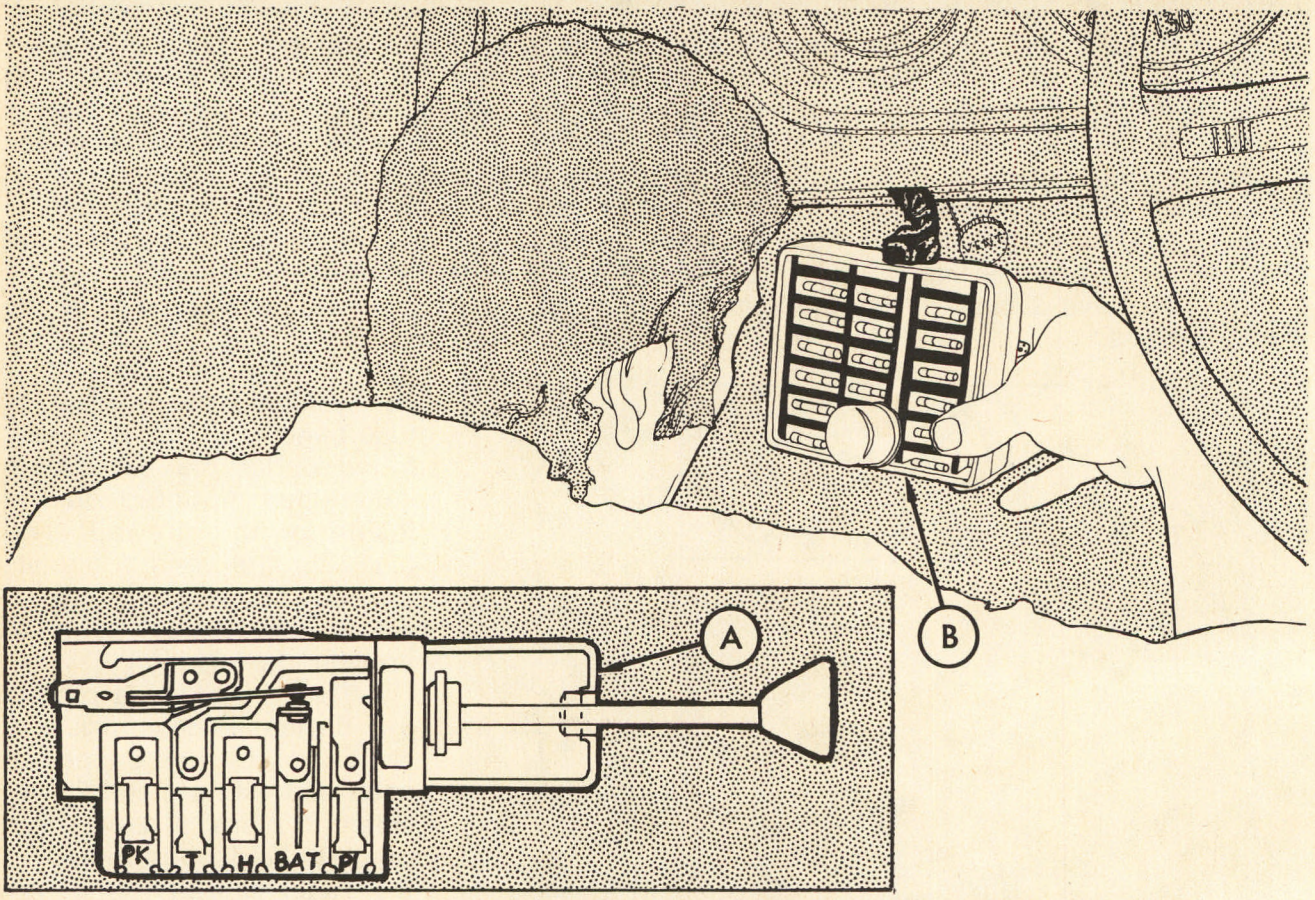
NOTE: IT IS BETTER TO CHECK ALL FUSES WITH A METER RATHER THAN RELY ON VISUAL MEANS. SOME FUSES WILL MELT AT THE CAP END AND NOT IN THE CENTER. THE TINY FUSE WIRE ON SOME FUSES IS DIFFICULT TO SEE, EVEN UNDER THE BEST CONDITIONS.

Fuses come in a wide variety of sizes and shapes, and each has a series of numbers and letters (C) printed on the metal cap. This gives the size and electrical rating of the fuse.

NOTE: DO NOT INSTALL A FUSE OF A HIGHER THAN SPECIFIED RATING IN ANY CIRCUIT. THIS COULD CAUSE DAMAGE OR EVEN FIRE IF THE CIRCUIT BECOMES OVERLOADED.

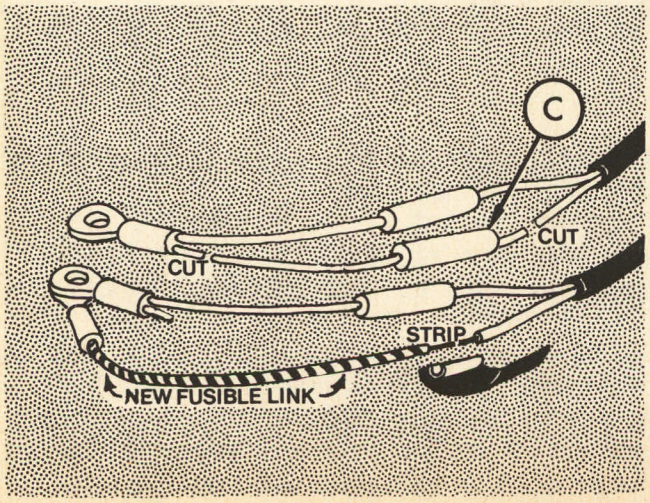
If examination of a circuit shows that the fuse protecting the circuit has blown, there is probably some trouble in the circuit. Momentary overloads can cause the fuse to blow, and they can also fail because of age or vibration. However, until you have checked the circuit and know it is good, a blown fuse should be considered as a warning of electrical trouble.

TROUBLESHOOTING ELECTRICAL ACCESSORIES



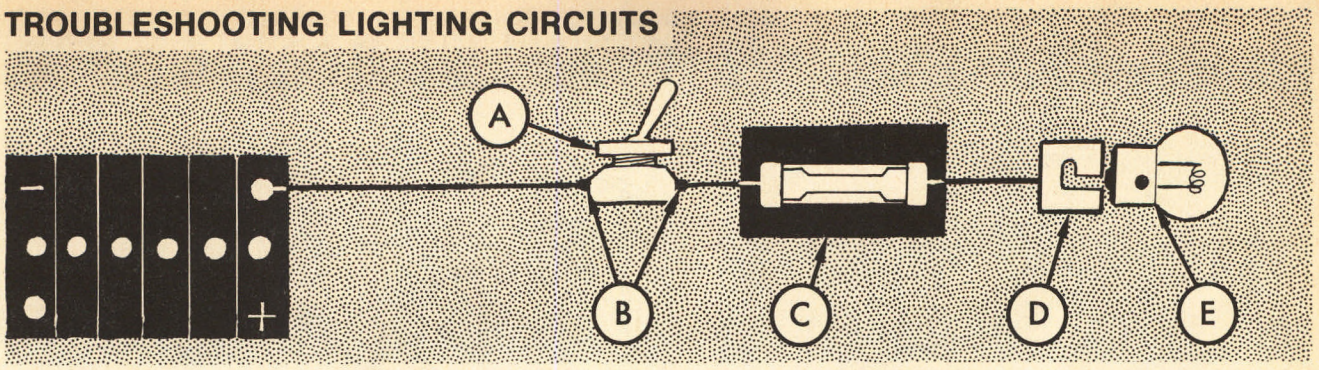
A newer device for protecting circuits is the circuit breaker (A). This small device is designed to break the contact like a fuse, but it will return to normal operation if the overload was momentary. The circuit breaker is often a sealed unit and cannot be serviced or repaired. If a circuit breaker fails completely, it must be replaced like a fuse. Circuit breakers may be located throughout the system, sometimes attached directly to the electrical part. They are usually a separate unit rather than grouped together on a block like fuses. The electrical portion of the shop manual will give the locations of the circuit breakers in your car, if it is so equipped.

Armed with the wiring diagram from the shop manual and an ohmmeter, it becomes easy to trace and locate troubles in the wiring system. The fuse block (B) is the ideal place to start, since all the major electrical systems have a fuse in its system. Voltage measurements can be taken directly from the fuse contacts while the system is operating, and resistance measurements can be taken with the power removed to check continuity of circuit wiring.



Certain circuits in late-model cars are protected by a device called a fusible link (C). This is a short section of wire inserted into the regular wiring that functions like a fuse if current flow becomes too high. Fusible links are usually marked with a special color or lettered tab, and they can burn out without showing any external change. It is wise to examine one closely before declaring it good while troubleshooting. If a burned fusible link is discovered, it can be replaced by cutting the old link out of the circuit and installing the new link with the aid of a soldering iron. The new link should be installed in the same place and should be cut to the same approximate length as the original.

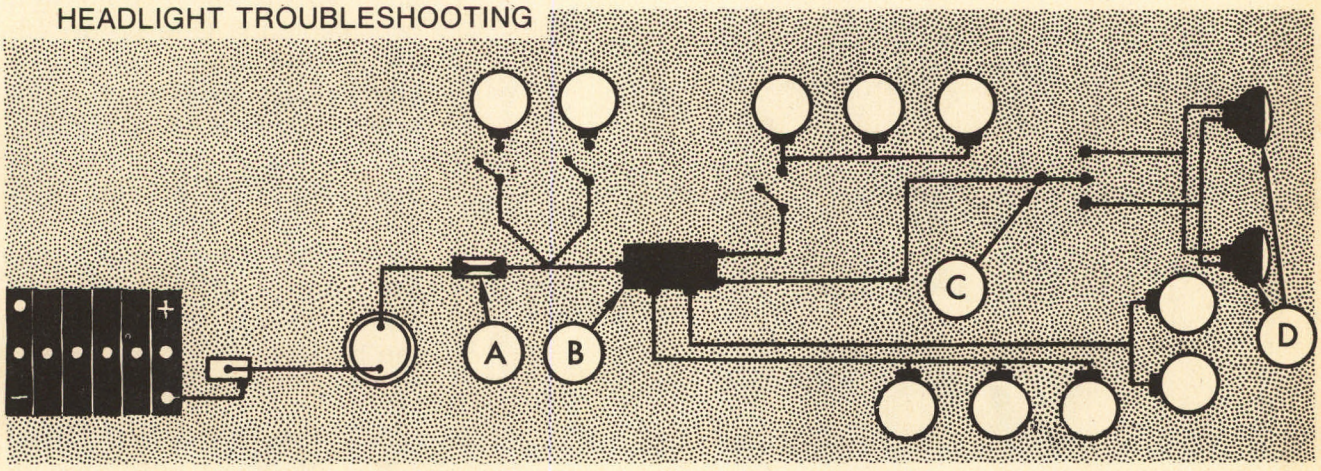
TROUBLESHOOTING LIGHTING CIRCUITS



Troubleshooting any lighting circuit is a relatively simple task. The procedure for checking any light is simple and straightforward. First, remove and examine the bulb (E) itself and the socket (D) it fits into. If the light and socket are good (no burned-out filaments or corrosion and dirt in the socket), go to the fuse panel. Check the fuse (C) for that circuit. If the fuse is blown, try replacing the fuse and checking again. If the fuse blows again, start checking the wiring in that circuit for possible short circuits or burned wires. If the fuse is good, check the circuit at that point for power. (Use the multimeter, set for voltage.) If there is power at that point, the wiring from the battery to the fuse panel is good.

Next check the switch (A) that controls the light. Check for power at the switch terminals (B). Remove power from the circuit and test the switch for continuity as explained in the chapters on troubleshooting ignitions and starters. If the bulb, fuse and switch are good and power is present at all points except the light socket when the switch is on, the problem is a broken or shorted wire at some point in the harness. See the shop manual and trace all wires in that circuit. Remember to closely examine any connectors in the wiring.

HEADLIGHT TROUBLESHOOTING



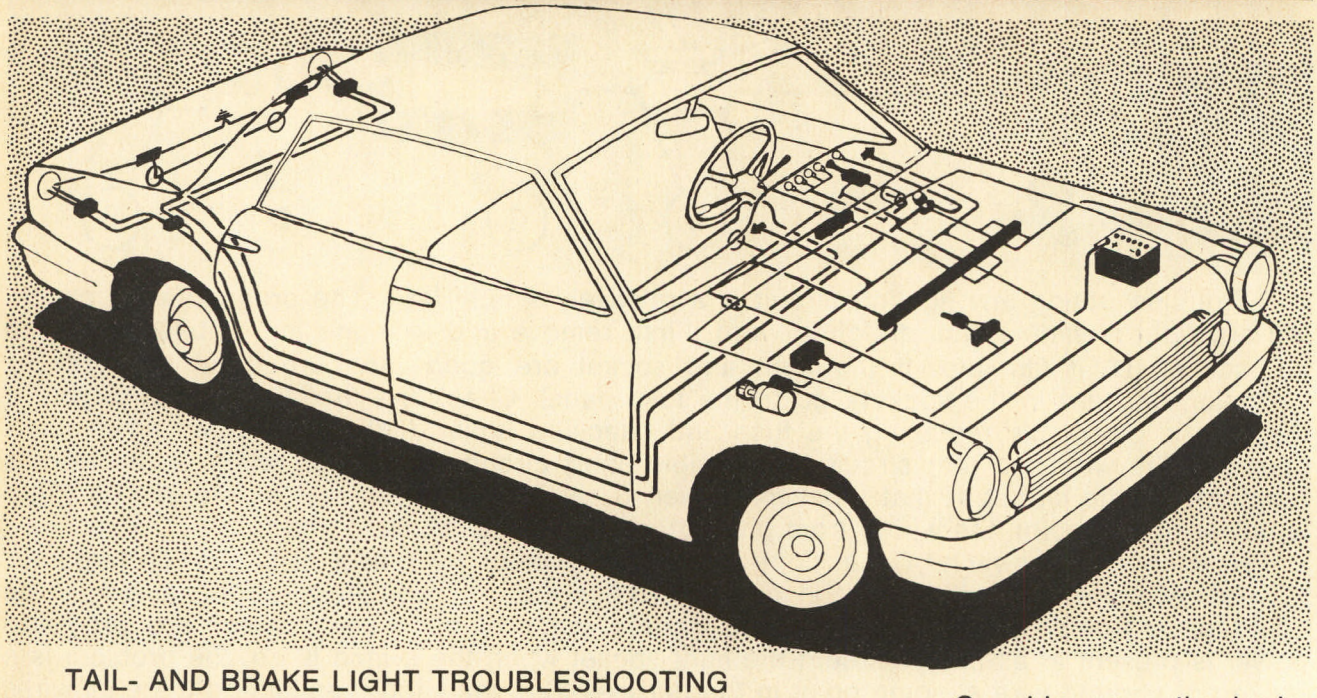
The headlight circuit consists of the headlight switch (B), the protecting fuse or circuit breaker (A), the dimmer switch (C) and the headlights (D). If the lights fail to switch from bright to dim or if they go out entirely when the dimmer switch is pressed, the problem is in the dimmer switch. This switch is mounted on the floorboard, with the underside of the switch and its wiring exposed to weather, road grime and moisture.

The headlight sockets themselves are frequently exposed to moisture and corrosion behind the grill. Check them carefully. The switch that turns the headlights on and off also controls the taillights, parking lights and license plate light. If the headlights will not operate at all and the fuse checks as good, one or more of these other circuits may be out also.

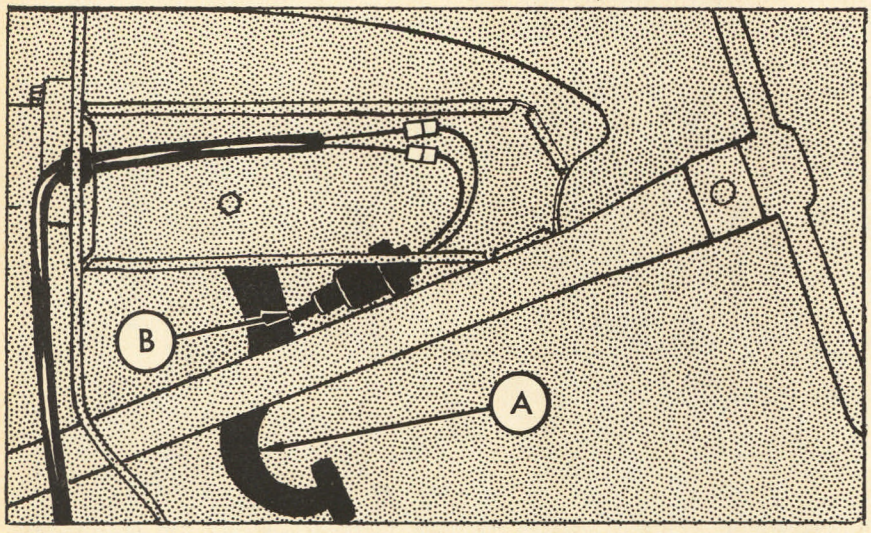
NOTE: IN MANY CARS, THE POWER FOR THE LIGHTING CIRCUITS COMES FROM THE BATTERY TERMINAL OF THE IGNITION SWITCH (BATT). THE POWER DOES NOT GO THROUGH THE SWITCH; IT IS SIMPLY A CONVENIENT PLACE TO CONNECT THE WIRING. IF TAILLIGHTS AND HEADLIGHTS ARE OUT, CHECK THIS CONNECTION.

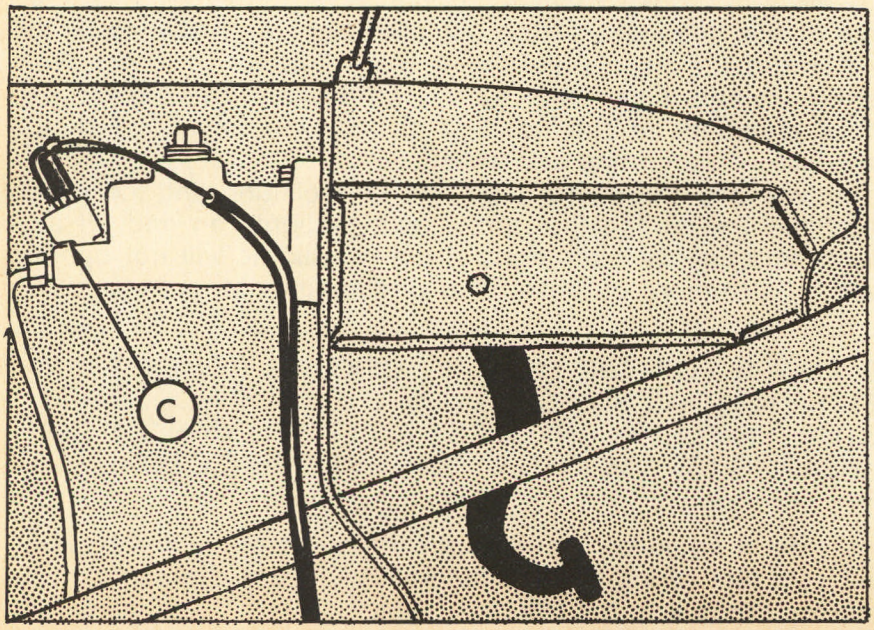
If the headlight is out on one side, it could be the fault of the light itself or of the wiring between the headlights. On many cars, the wiring is arranged so that it runs down the inside of one fender to the light, then across the grill to the opposite light.

TROUBLESHOOTING ELECTRICAL ACCESSORIES



TAIL- AND BRAKE LIGHT TROUBLESHOOTING



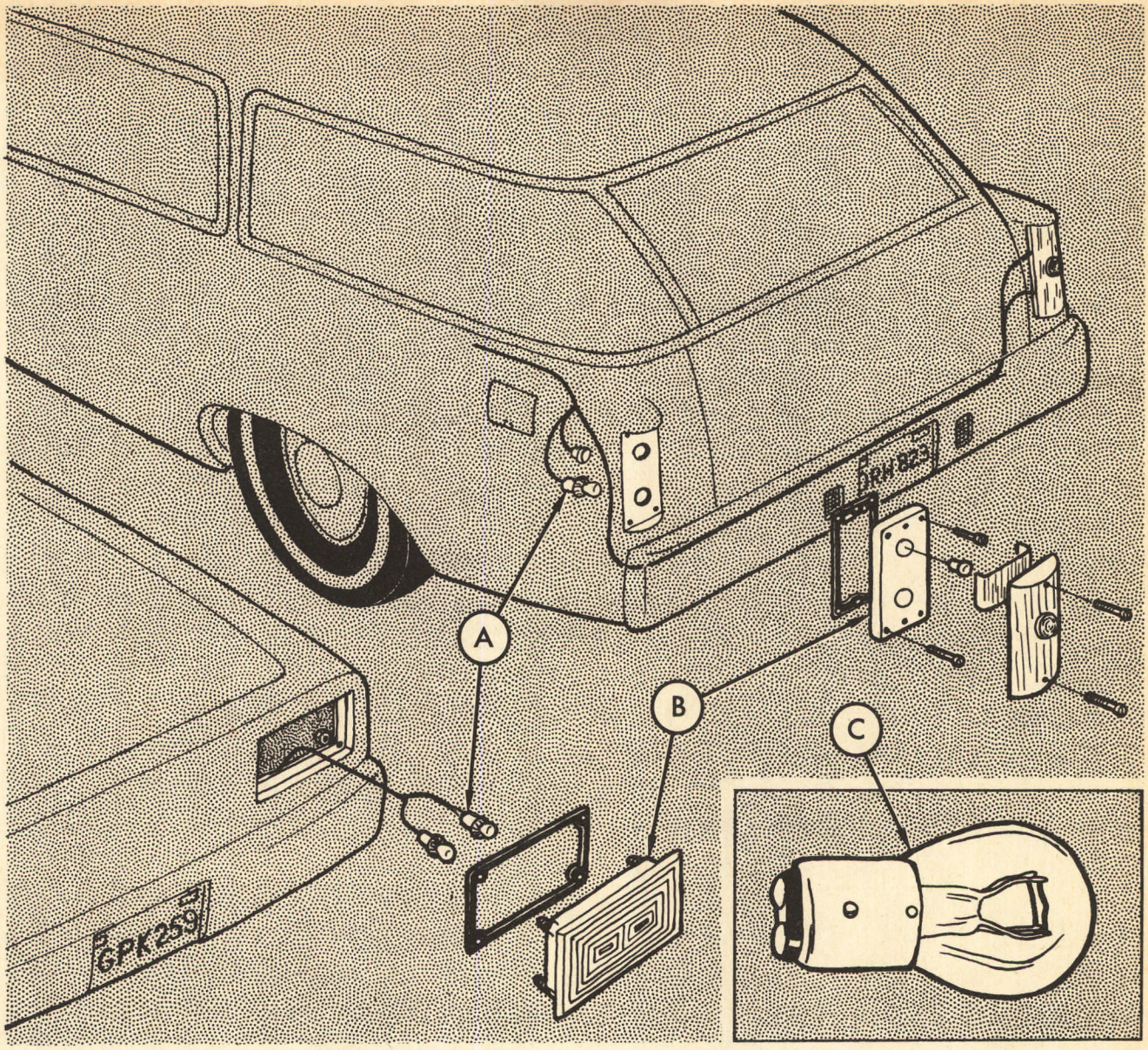


On older cars, the brake and taillights are combined units which use a bulb with two filaments. One is for taillights, the other for brake lights. New cars have separate brake and taillight bulbs. The taillights on all models are controlled by the light switch that turns on the headlights. The brake lights are controlled by the brake switch, which functions when the brake pedal is depressed.

There are two different types of brake light switch. One is a simple mechanical switch, which is usually mounted on a bracket near the brake pedal arm (A).

When the brake pedal is depressed, the switch button (B) is released and completes the circuit to turn the brake lights on.

The other type of brake switch is a hydraulic switch (C). This is mounted in the brake line, usually on or near the master cylinder. This switch senses an increase in hydraulic pressure as the brakes are applied and completes the circuit to turn the brake lights on.



On most cars, the rear of the brake light housings (B) is easily reached from the inside of the trunk. The bulb holders (A) are usually clipped in place and are easily removed to get at the bulbs. The most common wiring problem for taillights is a loose light bulb socket which is not establishing a good ground path for the return of the current. (In other words, the metal end of the bulb is not making good contact with the metal in the bulb socket.) Taillights are also subject to corrosion and moisture and should be examined carefully.

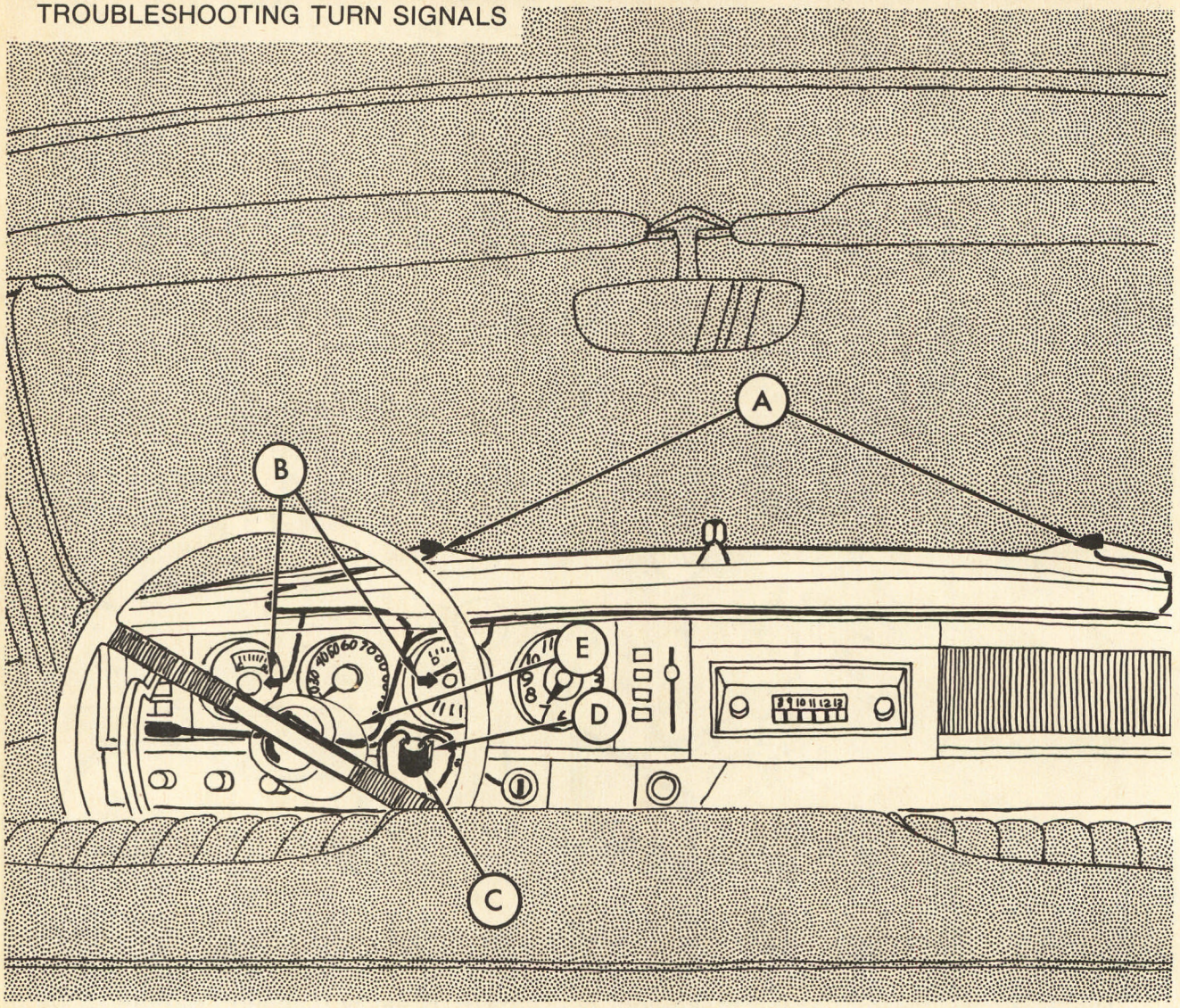
Taillights with dual-filament bulbs (C) can lose one filament without harming the other one. This will eliminate the taillight function without stopping the brake light or vice versa. It is also possible in some cars to install the bulb wrongly, so that the brake filament is lit by taillight power and vice versa. This gives the rear lighting an unbalanced effect, as the brightness of the tail and brake filaments are different. This error simply requires removing the bulb and reinstalling it in the correct position.

If the rear lights do not light at all (the license plate light will also be out), the problem is an interruption of power. Check all connectors in the wiring leading to the taillights and check the fuses for these circuits. If only the brake lights are out and the taillights are on, the problem is the brake switch, the brake fuse or wiring from the light switch which operates the lights. On models with the switch on the brake pedal arm, it may be that the switch is simply out of adjustment. See your shop manual for adjustment instructions.

Another problem which might occur is brake lights that remain on even though the brake pedal is not depressed. This can be caused by an out-of-adjustment switch as above, or in the case of the hydraulic pressure switch, it may mean that there is debris clogging the line coming out of the master cylinder, leaving some residual pressure to keep the switch closed.

TROUBLESHOOTING ELECTRICAL ACCESSORIES

TROUBLESHOOTING TURN SIGNALS

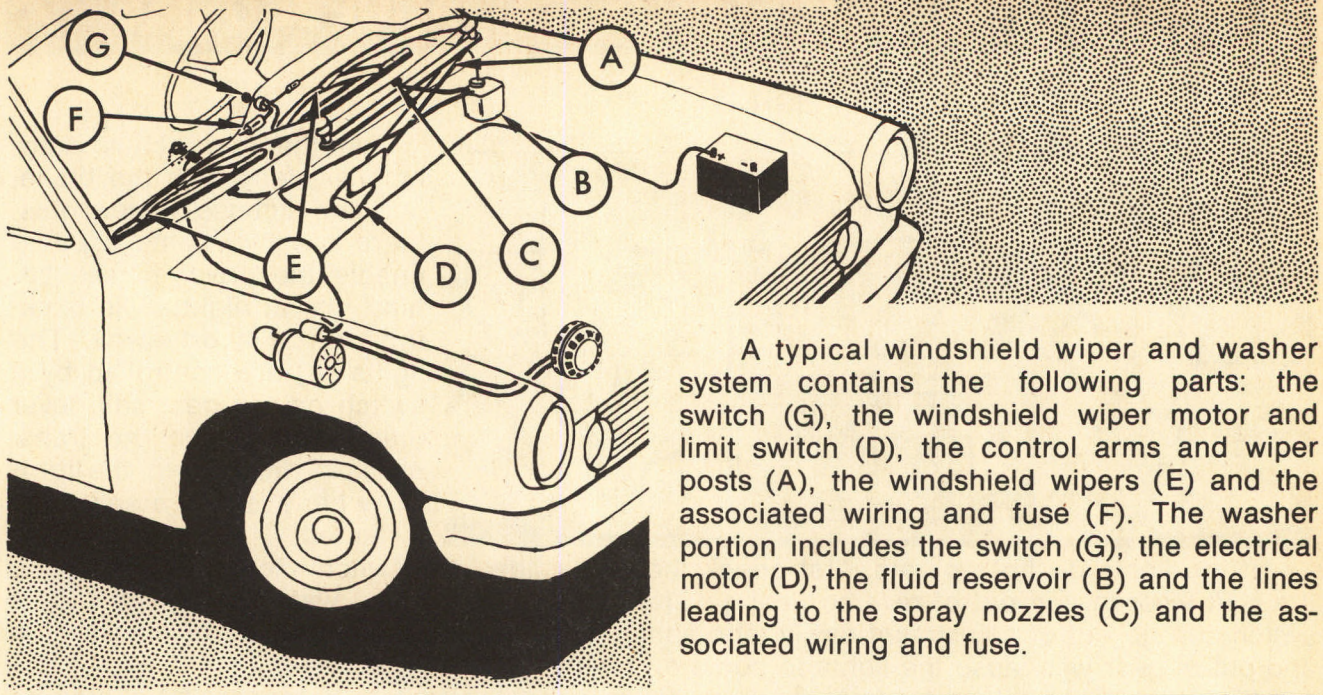


The turn indicator system uses the parking lights and brake lights to indicate the direction the driver intends to turn. (On some late-model cars, the turn signal lights in the rear may be separate from the brake and taillights.) The parts of the system include: the lights (A); the switch, mounted in the steering column (E); and the flasher unit (C), which produces the blinking of the lights by intermittently completing and breaking the electrical circuit (thus the clicking sound heard). Turn indicator lights are self-canceling in most cars. This means that they shut themselves off automatically when the steering wheel is returned to a position in which the wheels of the car are straight. The driver is informed of the operation of the turn signals by two small indicator lights (B) which are mounted in the dashboard (usually in or near the speedometer).

The turn signals have a built-in failsafe design. *All* bulbs on one side of the car must be working or the signal will not flash in that direction. If the indicator light burns steadily when you try to signal a turn, check the bulbs for that side of the car. If all bulbs check out as good, the problem is in the wiring or the flasher unit itself. If the indicator light does not light when you turn on the turn switch, check the flasher (C) and the bulb behind the green indicator arrows behind the dashboard. If you can hear the flasher clicking, it is probably okay. If the flasher is not clicking, a light tap with your finger will usually start it working. Flashers are usually located near the bottom of the steering post (E) or mounted in a clip (D). under the dashboard (middle or right-hand side).

If the turn signals continue after the turn is completed and the steering wheel straightened, the problem is in the self-canceling mechanism of the switch in the steering column. See your shop manual for information on checking or replacing the switch.

WINDSHIELD WIPER/WASHER TROUBLESHOOTING



A typical windshield wiper and washer system contains the following parts: the switch (G), the windshield wiper motor and limit switch (D), the control arms and wiper posts (A), the windshield wipers (E) and the associated wiring and fuse (F). The washer portion includes the switch (G), the electrical motor (D), the fluid reservoir (B) and the lines leading to the spray nozzles (C) and the associated wiring and fuse.

NOTE: WINDSHIELD WASHERS AND WIPERS MAY BE LINKED TOGETHER TO FORM ONE UNIT.

Windshield wipers are easy to troubleshoot but difficult to adjust if the automatic cycle is disturbed. We do not recommend that the reader take the wiper motor or the limit switches apart and try to repair or adjust them. If you are convinced that you have a problem in this area, take the car to a qualified mechanic for repairs.

If the windshield wipers will not operate at any speed, check the fuse (F) first. If the fuse and the wiring leading to the switch and motor look good, the wiper switch should be checked by bypassing it with a jumper wire. If the wipers work normally with the switch bypassed, the switch is bad and should be replaced. Non-electrical problems can also make the wipers fail to operate. Check the linkage and wipers to see if they are in a bind.

NOTE: GETTING AT THE LINKAGE UNDER THE DASH IS HARD ON ALL CARS, AND THOSE EQUIPPED WITH AIR CONDITIONING ARE ALMOST IMPOSSIBLE TO SERVICE AND TROUBLESHOOT.

Check your shop manual for information on how to gain access to the wiper linkage and motor.

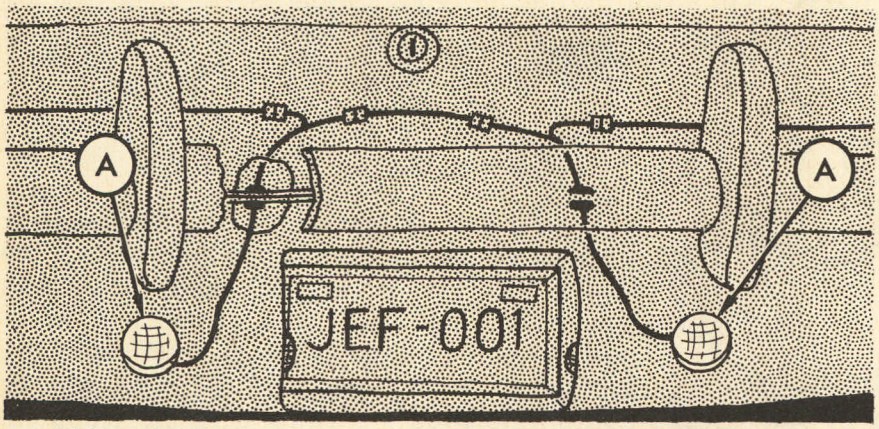
Most windshield wipers are multi-speed. Some have a special intermittent operation as well as high- and low-speed continuous operation. If the wipers will not operate in one particular switch position but will work in all the others, the switch is bad or the wiring for that switch contact is bad. Replace the switch and recheck the system. If the wipers will only work slowly even though the switch is placed in the fast position, the problem could be binding linkage or low power to the motor. Check the linkage and wipers and examine the wiring to the motor for signs of broken or frayed wiring. See your shop manual for information on how the motor is grounded and check for a good ground.

Windshield wiper blades that do not return to the stowed (out-of-the-way) position at the base of the windshield when they are turned off but instead simply stop wherever they are have a motor switch problem. The motor has a special switch section inside which sets the limits of wiper movement. This switch also returns the wipers to the stowed position when the power is removed by turning off the main wiper switch. It is not recommended that the reader attempt to adjust this switch. Take the car to a qualified mechanic for repair or adjustment.

Wipers that will not shut off unless the ignition switch is off may have a failure in either the motor switch or the system on/off switch. Each will have to be replaced in turn to find the problem.

TROUBLESHOOTING ELECTRICAL ACCESSORIES

TROUBLESHOOTING BACKUP LIGHTS



At the rear of the automobile, along with the brake, tail and license plate lights, there are two lights used to enable the driver to see behind him at night while backing out of a driveway. The lights (A) are controlled by a switch on the gear shift lever mechanism or on the transmission, which turns the lights on whenever reverse gear is selected.

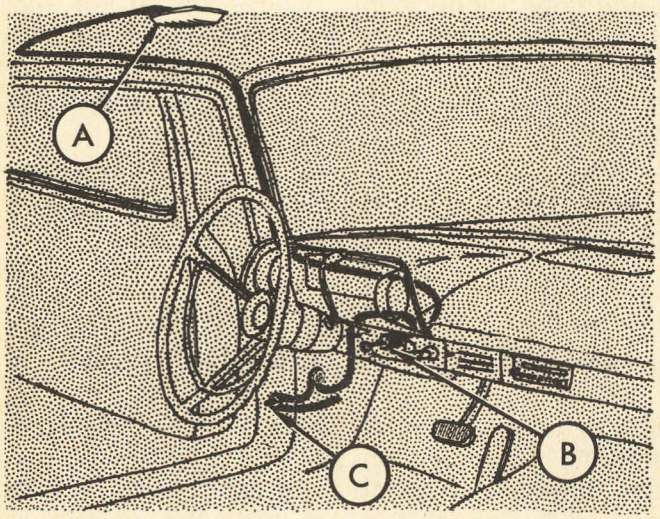
If the lights do not operate, first check the bulbs, then the switch. You may try moving the shift lever in and out of reverse gear several times while a friend watches the lights. This switch can go out of adjustment easily, and sometimes wiggling the shift lever or moving it in and out of gear will cause the lights to come on briefly.

If the lights cannot be made to work in this manner, the switch (if accessible) should be bypassed with a jumper wire to see if the lights will come on. If the backup lights work with the switch bypassed, the switch is bad.

Faulty wiring is often the cause of backup light failure. The transmission area is usually dirty and oily. This can lead to corrosion or a bad ground. Check wiring carefully.

You can troubleshoot several other small accessories, such as the clock, cigarette lighter, glove compartment lights, etc., by using the same methods described above.

TROUBLESHOOTING DOME AND COURTESY LIGHTS



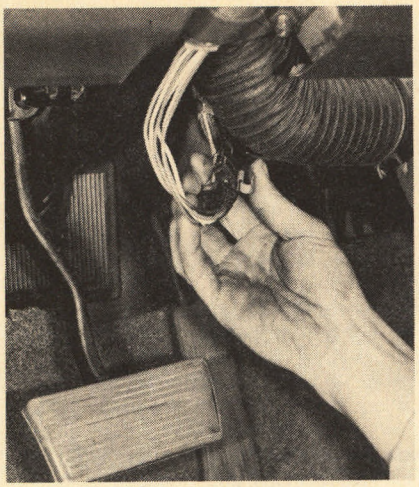
The interior of all cars is equipped with one or more lights which come on when the car doors are opened. On older cars they are usually mounted in the roof. Newer cars have smaller lights in the doors and at the base of the back seat. There is also a hand switch for turning the light on when the car is moving and the doors are closed. Usually turning the headlight switch (B) fully clockwise or counter-clockwise activates this switch. The door switch (C) is a simple, spring-loaded switch mounted in the door opening. It is operated by the opening and closing of the door. If the light does not come on when the door is opened, try the headlight switch or the dome light switch (A).

NOTE: MANY DOME LIGHTS ARE PART OF THE MAIN HEADLIGHT SWITCH. IF EITHER SWITCH WILL TURN ON THE LIGHT, THE BULB, FUSE OR WIRING IS BAD.

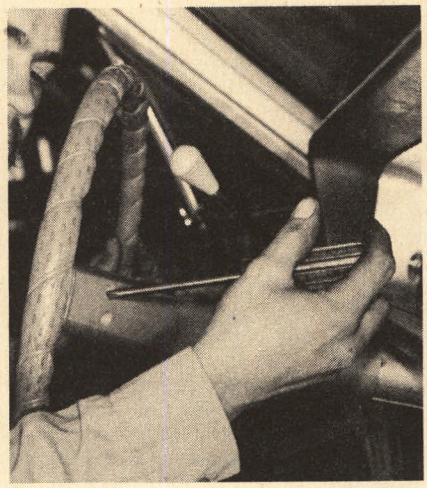
If the light comes on when the doors open but not when the manual switch (dome or headlight) is used, then the switch is bad. If the manual switch works but the lights will not come on when the doors open, the door switches could be bad.

NOTE: ON MOST CARS, THERE IS A SWITCH FOR EACH DOOR. YOU CAN CHECK THEIR OPERATION BY OPENING ONE DOOR AT A TIME WHILE WATCHING THE LIGHT OR BY OPENING THE DOORS ONE AT A TIME AND OPERATING THE SWITCH BY HAND.

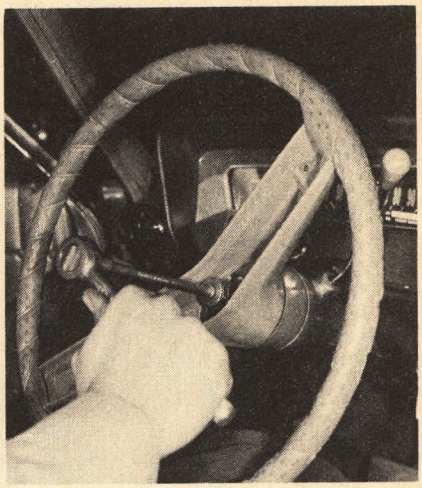
HOW-TO: Repairing Directional Signal



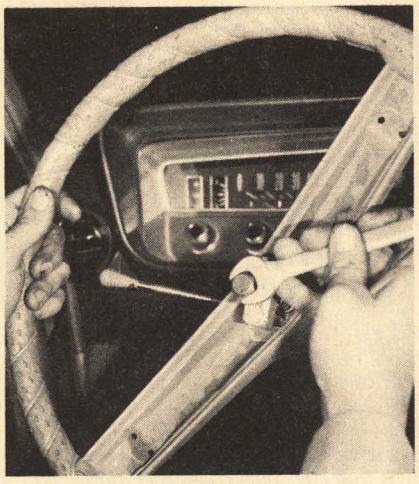
1. You'll have to pull the wheel if the directional signal cancellation mechanism doesn't work properly. Start by disconnecting the wiring harness.



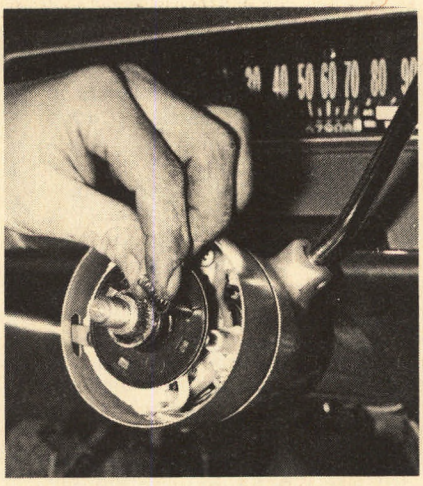
2. The horn actuator cap unit usually comes off when you remove the rear-mounted screws. Once these are free, the cap will just lift off.



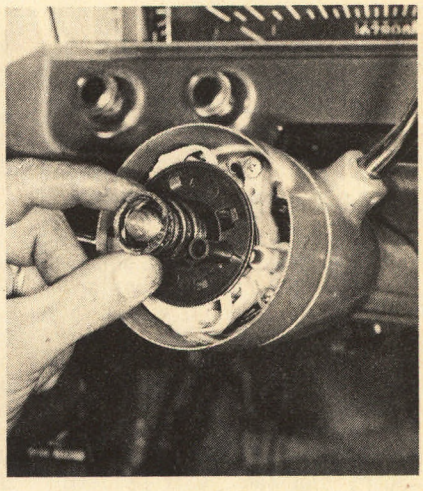
3. A socket wrench and a bit of arm muscle are needed to remove nut before pulling wheel. This may be a bit hard if the wheel hasn't been off before.



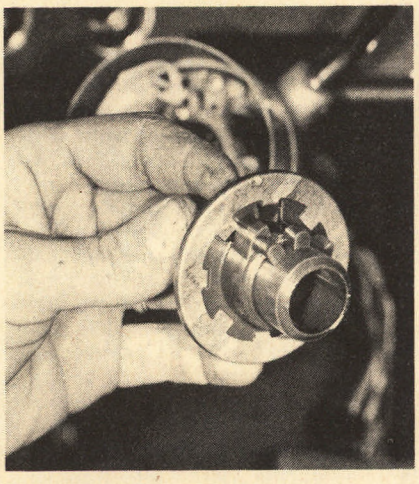
4. With a wheel puller fitted in place, an ordinary open-end wrench makes the job of wheel removal a real snap; you can't get far without it.



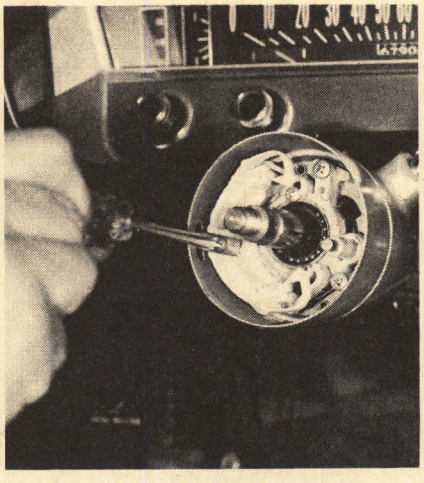
5. After lifting the wheel off, carefully remove the tension spring on the horn contact, if there is one. You'll be sorry if you lose this little fellow.



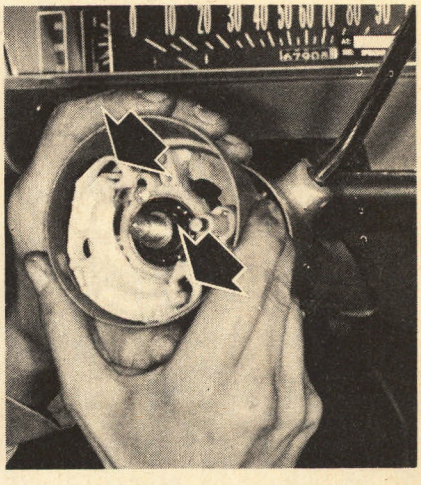
6. Remove the large spring on the shaft and the switch actuator plate beneath it will just lift up and off, thus revealing the signal mechanism.



7. The underside of the actuator plate shows the switch canceling lobes. And the circular brass plate that you see is a contact ring for the horn.



8. Three screws hold the directional mechanism in place, but the screw that holds the signal operating lever must come out first.



9. Mechanism now lifts out. Two screws separate it from horn assembly on right side. Plastic arms (arrows) operate with the actuator and often break.

Passenger Restraint Systems

The first known use of automotive seatbelts goes way back to 1908. The event took place during the New York to Paris auto race. After a few body and fender modifications, a 1907 Thomas Runabout was redubbed the Thomas Flyer and was entered in the race. In those days the mechanic rode with the driver, and since the race would be long and tiring, the mechanic had to catch his winks whenever possible. However, the Flyer had no doors and negotiating a sharp turn or two could mean losing a sleeping mechanic—quite embarrassing, and often a bit painful. As a precaution, a leather seatbelt, or strap, was improvised during the race and, apparently, it worked well because both driver *and* mechanic finished the race with the winning time. Shortly thereafter, restraint systems became commonplace in racing, but it wasn't until 1950 that they began appearing in the new-car dealerships.

FIRST FACTORY BELTS—NASH

American Motors claims to be the first to have offered seatbelts on a high-production car. In '50 and '51, belts and double beds were standard equipment on the Nash Airflyte ("bathtub" Nash) but, unlike the beds, the belts were rarely used and they didn't return in '52. For Detroit, 1956 was the year of the safety crusade. This lead to Ford's safety package, and to similar packages throughout the industry that same year. Padded dashes, visors and deep-dish steering wheels were available on all '56 models and, for the first time, dealer-installed seatbelts (advertised as exceeding FAA requirements) were offered by each factory as optional equipment, and even shoulder harnesses—another first—could be ordered on Chevys and Corvettes.

With the exception of Ford and Studebaker, the carmakers only quietly publicized the belts. Safety leaders Ford and Studebaker touted them (Ford even published an 8-page brochure entirely on belts), and their dealerships tried to sell them. However, this hard-sell approach may have cost them some sales, since it seemed to imply that their cars were unsafe.

The belts, made of heavy nylon webbing, were too stiff for retractors and many of them ended up tangled behind the seat only to be pushed aside and generally ignored. Unfortunately, regardless of system, public acceptance of seatbelts was low, and for '57 they were barely mentioned. In fact, reports show that less than 10% of the '56 Fords purchased had belts.

BELTS BECOME STANDARD

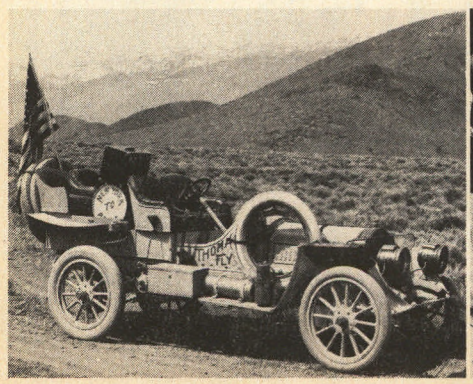
In '58, every Corvette leaving the factory left with a pair of belts, as did the Avanti in '63; but it wasn't until Jan. 1, 1964, that the belts became standard in all other American-made cars. During the 8½ years that seatbelts were available as an option ('56-Jan. 1, '64), an average of 20% of the new cars purchased were fitted with the belts. This low success rate proved that if seatbelts were made standard, only a minority of owners would use them. So, despite the safety campaigns waged by the industry, installing the belts in every car was clearly a waste of money. The American driver realized that it was safer to buckle up, but the majority of them felt too restricted and too uncomfortable doing so—they couldn't be bothered. Then one day in '63, the situation suddenly changed. The state legislators of New York and Wisconsin voted to make the belts standard in every new car sold in their states. There was some feeling that other states would soon follow; so, in anticipation, the industry standardized them on that first day of 1964.

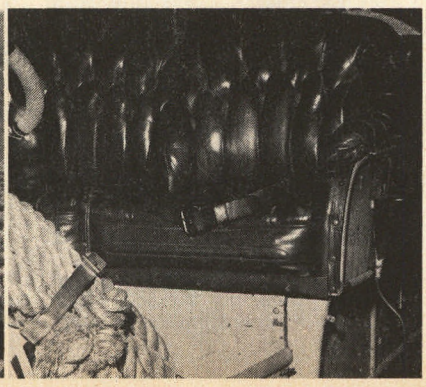
BELTS AND HARNESSES REQUIRED IN '68

Belts got thinner and more flexible and this permitted the use of retractors in '65, thus eliminating some of the hassle of having to find the belts before they could be used. Ford led the others in '66 by making seatbelts standard in the rear outboard seats and shoulder straps optional in the front; but everyone got in on the act in '68—they had to. Effective Jan. 1, 1968, Federal law required belts for each occupant and also shoulder belts (an extra $22) for (except convertibles) driver and outboard passenger. What a mess! Five buckles and one belt tongue on each front bench seat; it takes five minutes just to figure out who gets which belt. Initially, the confusion was so great that one man, Mr. B. Fuddle of Burgoyne, N.J., reported that when he was just beginning to feel confident about using the belts, he apparently buckled his own belt to that on the seat, and when he left the car, his pants fell off. Nevertheless, in time everyone learned to live with the restraints; but still, very few used them. In October of '68, only 35% of those owning seatbelts used them and less than 5% used their shoulder belts.

LIGHTS AND BUZZERS

Ford's '70 models ended the confusion with a new 3-point system that eliminated the buckles for the shoulder straps. The strap tongue (the end opposite the buckle) hooks onto the outboard lap belt tongue before or after the lap belt is buckled. New seatbelt retractors eliminated the need to adjust the belt for different wearers. The retractors lock the webbing at the desired length—in a manner similar to the mechanism in a window shade. Fewer buckles and new smaller buckles relieved the cluttered look of '68 and '69. For some reason, the other makers were slow in adopting Ford's 3-point system. American Motors introduced it in '71 and Chrysler in '72, while GM was still messing with five buckles until '73. 1973 Federal law required Detroit to include a seatbelt reminder in each new car to encourage greater use of the unpopular restraints. The systems used were nearly identical to Ford's system. However, this isn't too surprising because Ford voluntarily initiated the system on all '72 models produced after Dec. 1, 1971. A seat sensor in the front passenger's seat, and a switch in each of the two lap belt retractors determine whether or not the belts are buckled. If left unbuckled, a flashing light ("fasten belts") and a buzzer go off and they continue to operate until the belts are fastened. Most drivers soon learned to defeat the system by tying knots in the belts or by tucking the belt end under the carpet. Shoulder belts re-





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mained unused due to the absence of retractors, but '74 brought a change.

IGNITION INTERLOCK

In hopes of delaying the air bag, Detroit has reached way up its sleeve and pulled out the interlock trick. They had no alternative—the law says that all '74 U.S. cars must have it. Most of the '73 components were retained but now, in addition to the buzzer going off, the engine won't crank until all front-seat occupants have buckled the shoulder/lap belt combination. Interlock can be a real pain, but Detroit compensated by giving us some great new shoulder belts. The old design ('68 through '73) was much too confining, and without retractors they have to be folded to be put away. They require readjustment for each new wearer and once in place, provide very little movement for the upper torso. Stretching for the glovebox means unfastening the belt. They are obviously a nuisance. The '74 models all have shoulder belt retractors (inertia reels), and both lap and shoulder belts are permanently attached to one another making buckling a one-hand operation. However, the inertia reel retractors are the best news of all. The reel permits the user to move about, but under rapid deceleration they will lock up and restrain. All but Chrysler use the "vehicle-sensitive" type. A pendulum, or similar device within the mechanism, senses any panic stops and locks the harness snugly around the user. Chrysler uses the "belt-sensitive" type, which locks whenever there is a sudden pull on the belt. A quick movement by the wearer can lock it up, which can prove to be quite a drag for girl-watchers. By their comfort and convenience alone, the new restraints could increase use—but the interlock is there just to guarantee it.

1.This is the car that started it all—the 1907 Thomas Flyer. The Flyer (70 hp and four cylinders), is the first car to have used a seatbelt. The belt (right), added during the '08 N.Y. to Paris race, permitted the mechanic to snooze in place.

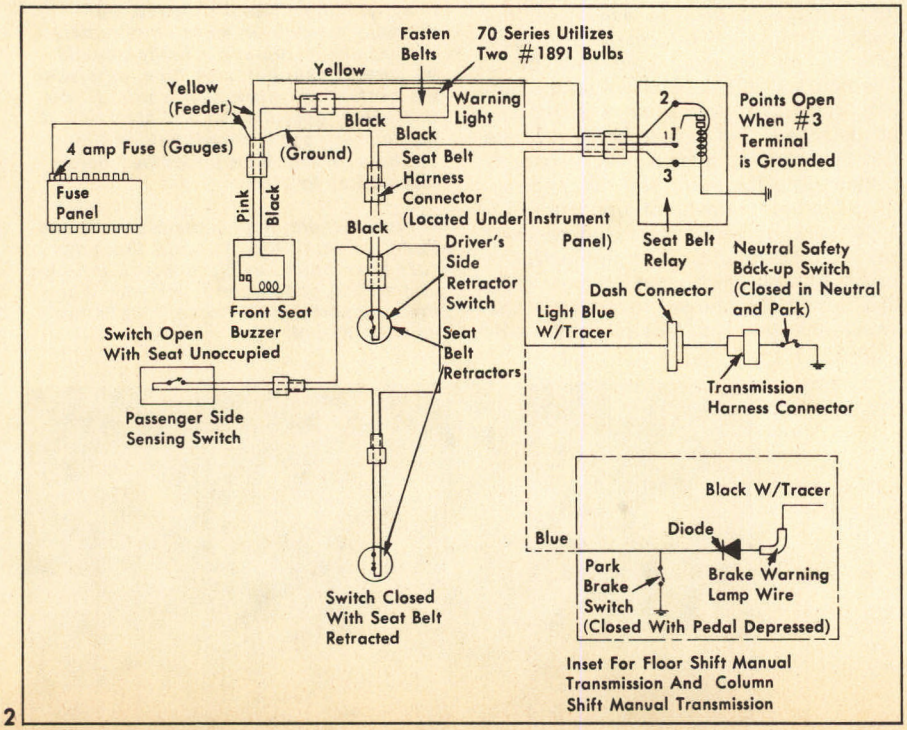
2. American Motors' seatbelt warning system (1973). On automatic transmission cars, the system is wired into the neutral safety switch located on the transmission. Cars with standard transmissions are activated by the parking brake pedal. With that one exception, the schematic is the same for all models.

INSTALLING AND REPAIRING RESTRAINT SYSTEMS

Prior to 1973, there's very little to know about restraint systems. Aside from the retractors and the buckle mechanism, there are no moving parts. Consequently, you rarely hear of a seatbelt going bad. However, with the advent of buzzers and lights, seat sensors and interlock, that story has changed—but more on that later. If your car falls into the category of pre '73 we suggest you hold on to it; meanwhile, here are a few words of advice on those models:

PRE '64

If you want to install seatbelts in a car that never had them (pre '64), be sure to use only approved (preferably those available from the car dealer) belts and hardware. The floor you are bolting them to must be solid and free from rust; merely bolting them to sheetmetal won't make it. If you install belts in an old car, make sure you reinforce the sheetmetal with steel plate. Once the belts are anchored, it's strongly suggested that the underside of the floor be made rust-free and then undercoated to prevent future rusting. When installing the anchor bolt (lap belt or shoulder belt) on any car, remember to avoid cross-threading by starting the bolt with your fingers before using a wrench. Tighten the bolts to the correct torque.



'64 THROUGH '72

If, for some reason, a belt has been damaged, replace both ends of the set, not just the damaged half. If you use a new buckle with the original tongue, it might not hold properly. If a retractor decides to quit working, don't try to repair it, replace it instead. Unfortunately, the belt is part of the retractor so you're going to have to spring for the belts too. Individual retractor parts aren't sold to the public. If the mounting hardware has been damaged or lost, replace it with *only* those parts specified by your car dealer's parts man.

BUZZERS AND FLASHING LIGHTS—1973

The information supplied above in "'64 through '72" also applies to the '73 and '74 models. The systems are the same in those respects, but that's where the similarities end. As you will see, the '73 cars and all '72 Ford products built after Jan. 1, 1971, had a complex seatbelt warning system. The system attempts to encourage seatbelt use with a very annoying buzzer and a flashing "fasten belts" sign.

Here's what happens: Climb behind the wheel, turn on the ignition switch and place the transmission into reverse or a forward gear (if automatic), or if the car is standard shift, release the parking brake. At that moment, an obnoxious buzzer will sound from behind the instrument panel and a flashing light will tell you to "fasten belts." Reach down and withdraw the lap belt about 10 ins. from the retractor. If everything is working right, the buzzer and light should go off. Keeping the car in gear (or the parking brake off) and the ignition on, fasten your belt and have a passenger sit in the front outboard seat. As the passenger's weight hits the cushion, the buzzer and light will again turn on. Extending the belt from the retractor will shut them off.

Basically, the system consists of a flashing light on the dash, a buzzer behind the instrument panel, a relay (usually behind the instrument panel near the glovebox), a switch in each of the two lap belt retractors, a pressure-sensitive switch beneath the right front (outboard passenger) seat cushion and a wiring harness connecting it all together. The wiring also hooks into the ignition switch and the neutral safety switch (automatic transmission), or the parking brake warning light on stick-shift cars.

HOW IT WORKS

That's what it does, now how it does it is something else. Turning on the ignition switch sends current to the neutral switch at the transmission (automatics) or the parking brake warning light (std. transmission); it then goes to the driver's retractor switch and on to the seat sensor under the passenger's cushion, then over to the passenger's retractor switch. If the transmission is in Neutral or Park or if the parking brake is on, those switches are open and the electrical cur-

rent can go no further. Shifting into forward or reverse or releasing the parking brake will close those switches, thus sending current to the retractors and seat sensor, and also to the light and buzzer. The buzzer will sound and the light will flash until the driver extends his lap belt enough to trigger the switch in the retractor. Extending the belt opens the switch, and current to the buzzer and light stops and they shut off . . . aaaah silence. OK, once the driver has buckled (or tied a knot in the belt or buckled the belt and sat on it), everything is cool until his dog jumps on the passenger seat. The sensor in the seat cushion can be sensitive to weights of 0-50 lbs. or more, so the weight of a dog or a package or, naturally, a passenger, can close the switch, allowing current to the retractor and onto that annoying buzzer. According to its sensitivity, the seat sensor can be easily disturbed. An object wedged between the cushion and seat back or merely leaning a hand on the cushion can do it. Opening the circuit to the buzzer (thereby silencing it) can be done by withdrawing the passenger's (outboard) belt enough to open the retractor switch. Therefore, any packages should be stowed on the floor or in the back.

SYSTEM WON'T OPERATE

If your warning system fails to operate, check the fuse box for a bad fuse. If you find a bad one replace it, and if it blows again check for a short (a grounded wire) or a loose connection under the dash. The buzzer or warning light may be bad, but usually one of them will work. If the system still fails to work, check for loose connectors (especially at the relay) or an open circuit (use a continuity tester) in either the body wiring harness or the instrument panel harness. If an open circuit (pierced or broken wire) is found, repair or replace the harness. Check the relay for proper ground, using a test lead to ground out the relay. The relay provides the ground for the buzzer and light and, normally, its contact points are closed, permitting current to flow through to complete the circuit. If the buzzers then work, you know that the relay is bad or improperly grounded. If the car starts in forward or reverse, then you know that the neutral safety switch on the transmission is faulty, and this will affect the warning system. On stick-shift cars, check for a bad parking brake warning switch. If the parking brake warning light doesn't work or it doesn't go off when the brake is released, then that switch is bad or a wire is shorting out on the frame. This would stop current to the buzzer and light. If all those things prove to be good, then the problem probably lies in the retractor switch—either from improper grounding of the switch or a bad switch. Check the ground and if OK, check continuity at the switch terminals and, if the circuit is open with the belt fully retracted, replace the retractor and switch assembly. (Remember, this includes both belt halves.) If light and buzzer don't come on when the passenger is seated, check the passenger's retractor switch. Switch contacts should be closed with the belt fully retracted, if not, replace the retractor assembly. Place weight on the seat cushion and check the seat sensor terminals to assure that the contacts are closed. If open, replace the sensor as described below.

BUZZER WON'T SHUT OFF

Now here's a problem. What if your buzzer won't shut off? Check first for any shorts at the seatbelt retractors. Check the retractor switch terminals with a continuity tester. If the contacts are open with the belt fully extended, the switch is all right; if they are closed, replace the retractor and switch assembly. The problem may also be a short in the seat sensor. Disconnect the seat switch connector and check to see if the switch terminals are shorting to ground when the switch is under weight on the cushion. If a short is discovered, replace the switch. Unfortunately, this requires that the seat be detached from adjusters, or from the floor, and tilted backward. Find the switch and remove it and install a new one making sure it goes in the exact same place. GM bench seats and swivel buckets require that the right side trim cover be loosened from the seat cushion just enough to provide access to the switch. The switch is cemented to foam padding, so you must break that bond. The new switch has adhesive on the bottom. American Motors seats must also be detached, and bucket seats are like GM bench seats because the sensor is cemented to the foam and this necessitates partial removal of upholstery. A super-sensitive seat sensor (betcha can't say it ten times) can cause the buzzer to sound with an empty seat. In most cars, this would be cause to replace the switch, but American Motors' design permits sensor adjustment without removing the switch. Switch sensitivity can be set by bending the switch's contact strips. With each adjustment, kneel on the seat until the cushion bottoms out. When the weight of a 50-lb. object can sound the buzzer then the adjustment is correct. Apparently, AM is the only one with the adjustment provision; a new switch is necessary on the others.

'74 INTERLOCKS

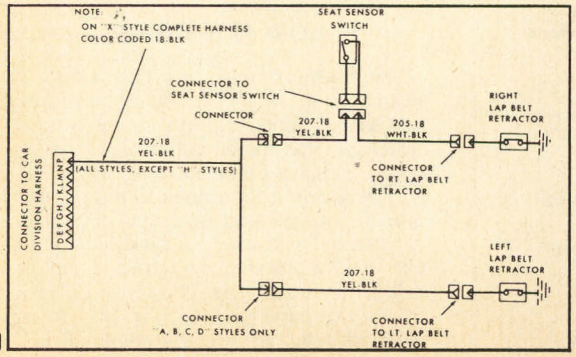
The '74 interlock is basically the '73 warning system combined with an ignition interlock. Interlock prevents your car from being started until all front seat occupants have buckled their belts. The secret to the system is a little black box—an electronic box (the logic module) containing a sequence circuit. A certain sequence of events must be satisfied before the box will allow the car to be started. You must sit in the seat and then buckle the belt before the car will start. The old trick of sitting on buckled belts or tying a knot in the belt doesn't work anymore. However, sitting on the seat first and then buckling the belt behind you does work; but it must be unbuckled and then buckled again each time you leave the car. Each front seat

1. If you've got troubles with the warning system on your '73 GM car, here's the diagram to follow. A, B, C and D styles refer to all body types except Camaro and Firebird (F), Nova, Ventura and Omega (X) and Toronado, Riviera and Eldorado (E). The H body type is the Vega.

2. This is the schematic for Mopar's interlock. The neutral start switch (also called neutral safety switch) indicates that this is the automatic transmission model. The standard transmission cars are hooked into the parking brake.

3. General Motors' interlock. For '74, GM uses two types of logic modules—an electro-mechanical (relay) type or an electronic type. The belt switches on the relay type are normally closed, but normally opened on electronic models. If you have to replace a faulty module, be sure to use the same type, otherwise the system will work backwards. If you use wrong one, the car will start only if the buckles are fastened before sitting on the seat and then unbuckled before turning key to start.

4. Ford owners, especially Mustang and Pinto, beware! Reports show that your cars have been having interlock troubles and so this schematic is for you. When that guy said "get a horse," that's not what he meant.



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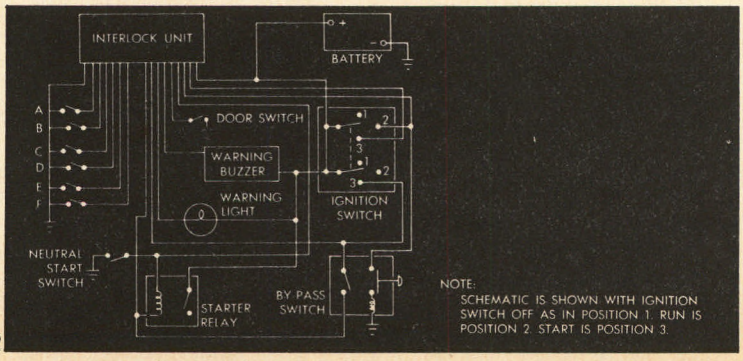

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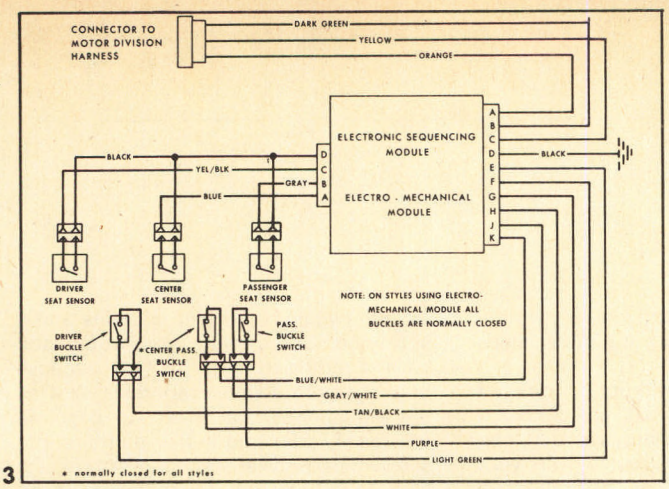

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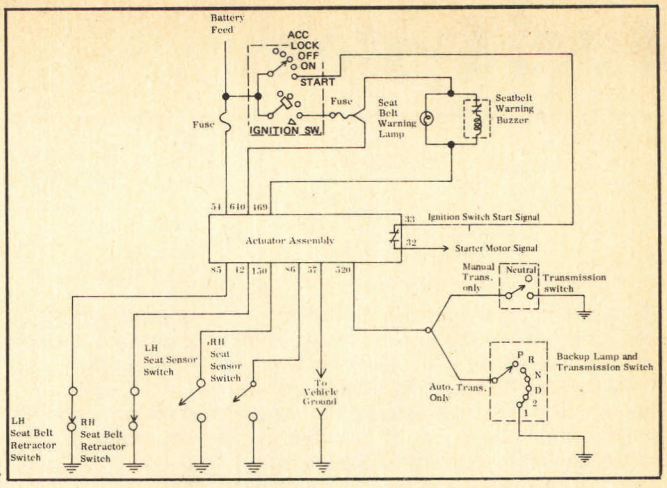


4

occupant has a sensor buried beneath his seat cushion—one for each bucket and three for a bench seat. GM, AM and Mopar front seat buckles all contain a switch; Ford's switch remains in the retractor. The switch is normally open, and when the belt is buckled it closes, permitting current to pass on to the logic module. If everything is working correctly, the following should occur: Sit down and turn the ignition key to the start position. The buzzer and flashing light will go on and the engine will not crank. The sensor beneath the seat cushion has been activated and current is sent to the logic module—step one of the sequence has been satisfied. Buckling the belt or extending the belt from its retractor (Ford products) closes the switch in the belt and sends current to the module to satisfy step two; it also permits current to flow to the starter solenoid for engine cranking. At this time, the warning buzzer and light go off.

American Motors ties their system into the door switches and domelight. When the door is closed, the light goes out and the seat sensor switch is activated. This allows an occupant to rise from the seat (thus opening the seat switch) for any amount of time without activating the buzzer and light and without preventing the engine from starting. That is, as long as his seatbelt remains buckled. However, if either front door is opened or if the domelight is turned on, there will be a 2-sec. delay and then the buzzer and light will come on. A signal is sent to the module and it interprets this as an occupant leaving the car. If an occupant leaves his seat for more than 2 secs., the same thing will occur. Ford and GM use a different type of time delay. Ford allows 15 secs. for an occupant to get adjusted in his seat. Without this delay, a person would sit down (thereby activating the seat switch) and buckle up; but, if in getting comfortable, he bounces from the seat, the switch would open requiring that the correct sequence be repeated. This 15-sec. delay gives him time to do his bouncing around before starting the car. GM's delay is from 5 to 100 secs. long.

Unbuckling a belt after the car has started will not stop the engine, but it will turn on the warning light and buzzer. As on the '73 models, this will occur only if the car is in gear (automatic) or if the parking brake has been released (std. transmission). If the engine should stall, it's not necessary to unbuckle and re-buckle the belts, as long as the driver stays in his seat. It's advisable to place all packages or pets on the back seat, because their weight may be sufficient to trip the seat sensor and prevent the engine from cranking. However, they can be placed on the front seat if that seatbelt is buckled.

TROUBLESHOOTING

The ignition interlock system is very complex and troubleshooting one requires a lot of time and many different tests. The procedure is so time-consuming that AM and Mopar have provided their dealerships with a pretty impressive-looking analyzer to do the job. Chrysler's shop manual also includes alternate troubleshooting using a voltage test light and a jumper wire, but it took them nine full pages to present it. GM's, AM's and Ford's systems are just different enough to necessitate separate troubleshooting procedures. Unfortunately, we don't have the room in this "Basic" book to fully cover each and every system, but we will include some of the more general checks that you can make. If the proper sequence has been followed and the engine won't crank, everyone in the front seat should unbuckle and buckle again to ensure proper switch operation. If the engine still won't start, pop the hood and locate the interlock bypass switch. It's usually on the fender panel or the firewall. The switch can be recognized as a little box with a button on top, and can often be identified by a decal. CAUTION: Before touching that button, make sure the car is out of gear and the parking brake is set; otherwise you just might get run over should the engine start. Press and release the button. This will bypass the interlock and permit conventional starting. You must release the button or it will not work; and, for the same reason, taping the button shut will not defeat the system . . . sorry. After releasing the button, turn the ignition key to start and if the engine starts with the bypass, then something is wrong with the interlock system. If it fails to start, then the problem lies in the ignition or starting system. If the engine cranks but the driver hasn't buckled his belt, disconnect the bypass switch connector and turn the key to "start." If the engine doesn't crank, replace the bypass switch. If that wasn't the culprit, check the wiring for shorts. Your next move is to inspect the driver's seat switch with a test light. The light should go on with the seat occupied and off with it empty. If OK, the problem is in the logic module. If the module (GM—under seat, all others behind dash) is bad, it usually affects both the warning light and the buzzer. If only one of them fails to work, then the module is still good. If the warning system does not go out when it should, then the buckle switches should be checked, followed by the seat switch. If both are OK, the module is faulty.

PROBLEM BUICKS

Buick has warned its dealers that their seat sensors are always activated, and leaving a package on the seat or failing to unbuckle seatbelts can drain the battery. Some '74 Buicks were built with misplaced seat sensors. The sensors were situated too far forward on the cushion, thereby making trouble for featherweight drivers or persons with good posture. The guy who sits up straight and firmly against the seatback will be too far back to activate the sensor. The results are: a car that starts with the belts unbuckled or one that won't start with belts buckled; or maybe this all explains why the buzzer and light come on while driving. It's suggested that the driver gain some weight or slouch a little until the new seat trim loosens up.

DON'T FIGHT, JOIN

Parking lot jockeys have discovered that interlock can be beat if you start the car before touching the seat—but then you have to contend with the buzzer. Although, like the seat sensor, the buzzer is easily disconnected. However, Detroit has finally come up with a comfortable restraint system, and that, combined with interlock, could encourage a rise in users. Belts do save lives and they're certainly cheaper than air bags—and probably safer too. If enough people use the new restraints, the death rate will definitely drop and the bag just may disappear.

Fuel System

It's unfortunate that the carburetor is up on top of the engine, because in that position it's too easy for everybody to fiddle with. Most so-called carburetion problems are caused by ignition timing, spark plugs, loss of compression, inadequate fuel delivery to the carburetor, or maybe even a clogged air cleaner element. The carburetor itself rarely gives much trouble in normal operation.

Spark plugs, coil, distributor, engine compression, engine vacuum, anf fuel delivery should all be checked before you tear into that carburetor. Not that carburetors can't cause trouble. It's just that carburetor trouble usually comes on slowly from an accumulation of dirt. Breakdowns and other malfunctions that occur suddenly like a thunderstorm in the middle of a big blue sky are not usually caused by the carburetor itself.

Carburetors have so few moving parts that there really isn't much in them that can wear out. The throttle shaft or the accelerating pump are probably the biggest offenders in the wear department. The throttle shaft wears from the pressure of the throttle return spring and lets air into the engine where it shouldn't be, or at least not very much of it. The accelerating pump plunger wears out and doesn't squirt as much as it should, causing a flat spot when the driver steps on the gas.

The rest of the carburetor doesn't have any significant wear points, but it has about a jillion points where it can get dirty. If you have trouble with your carburetor, the chances are about a hundred to one that it's caused by foreign matter reaching the carburetor through the air or through the fuel, or by gummy fuel deposits.

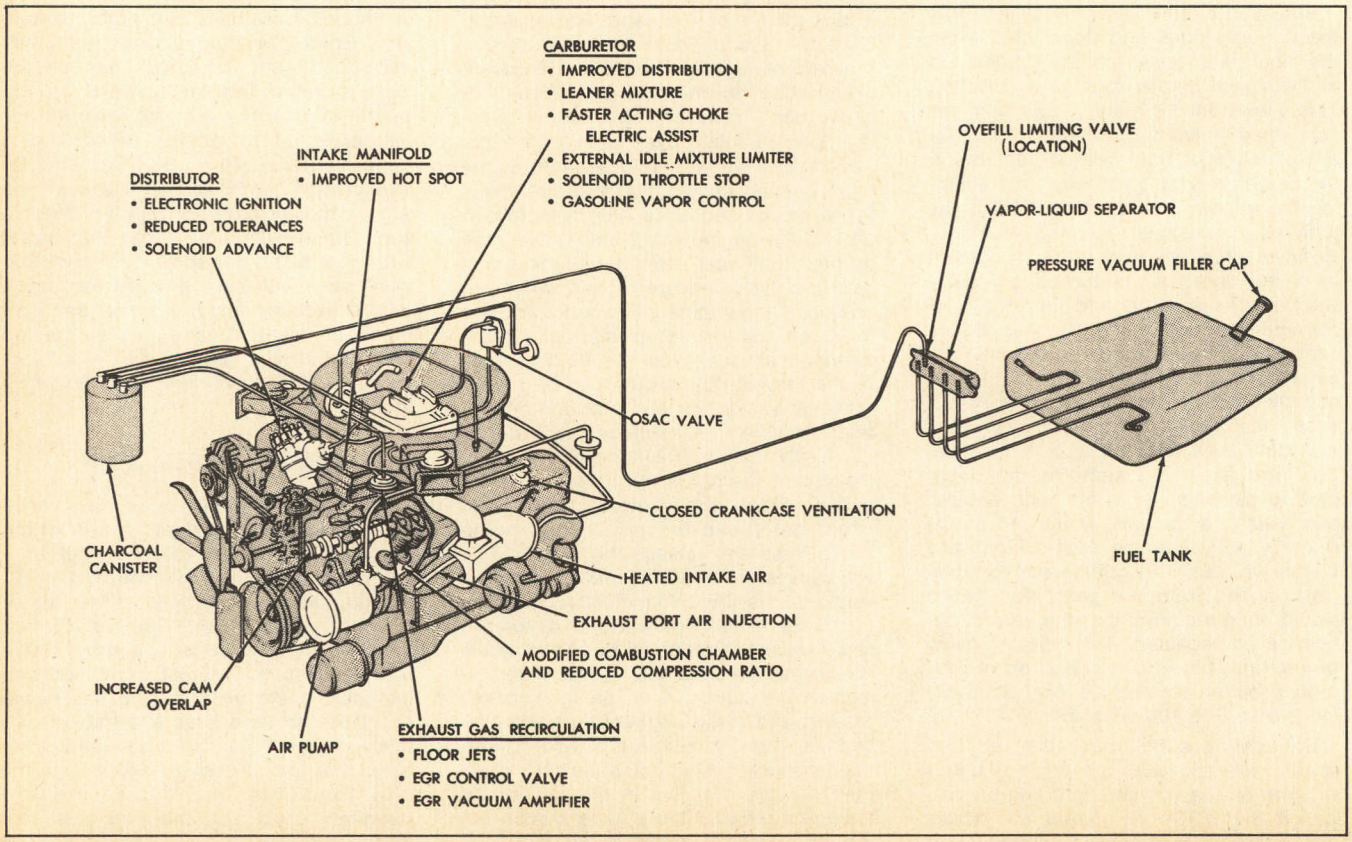
Did you ever drive a car that stalled at every signal? Maybe you've known of a car that lost power when it got up to cruising speed, or maybe you know somebody whose car billows black smoke out of the tailpipe as he drives down the street. Those things can be caused by dirt trapped in the carburetor.

The dirt or foreign matter may be rust particles that slough off the sides of the gas tank, or dust in the air that is inside the tank. When the dirt is carried up to the carburetor by the fuel, it means trouble. Airborne dirt gets lodged in the air bleeds and passages, upsetting the balance between air and fuel that the carburetor is made to control.

And even if you had a perfectly clean atmosphere for your engine to operate in, with hygienically clean gasoline and a scrubbed fuel system, you would still have a dirty carburetor in time because of the way gasoline evaporates. Not all the substances that make up gasoline will readily pass into the air and turn into smog. The heavier fractions of gasoline turn to a kind of gooey mess which eventually hardens about the same as a good brand of household glue.

So dirt is the primary enemy of the carburetor. A good tune-up man's carburetor work consists mostly of disassembly, cleaning, and reassembly, without making any adjustments at all. This is true even when he replaces parts, such as accelerating pumps and needle seats. The old and the new parts go back into the same positions, so that all he has to do is make careful checks of specifications.

However, there is one other cause of trouble in carburetors that has plagued good tune-up men since the first carburetor popped and sputtered into life. That cause is the inept workman. Call him backyard mechanic, peppertree mechanic, garage mechanic, tune-up expert, or just plain car owner. It doesn't matter what his title is or where he works. If the man working on the carburetor has



1. Chrysler Emission Controls

not taken the time to learn a little bit about how it operates, then he is going to cause trouble not only for himself, but for every mechanic thereafter who tries to undo his well meaning but fumbling fingers.

Trying to correct malfunctions can take an awful lot of time if you don't know what you're doing. You could spend days taking a carburetor apart, putting it back together, running the car and then going back through the same procedure all over again, simply because when you get the carburetor apart you don't know what to look for.

Other malfunctions cannot be seen, but once you know how a carburetor works all you have to do is stop, look, and listen, because the carburetor is trying to tell you something if you have the knowledge to understand it.

Now let's take a look at what makes the carburetor the smoothly operating mechanism that it is, with quick descriptions of the six basic systems.

1. Emission Controls for 1973 are the most complicated yet. This is Chrysler Corporation's latest.

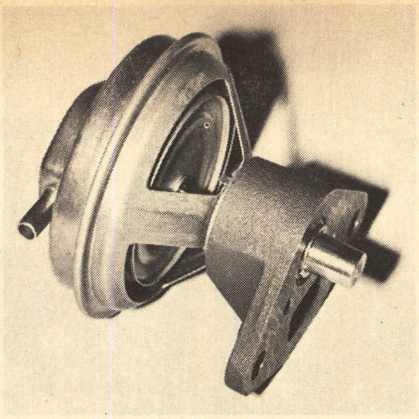
2. This little beauty is mounted on the intake manifold of '72-'73 Buicks. It lets exhaust gas recirculate into manifold at throttle openings above idle.

3. Six-cylinder GM engines have two electric gadgets for '72-'73. Upper one is familiar CEC valve. Its stem (1) is for CEC valve setting. Solenoid body (2) is turned to set curb idle.

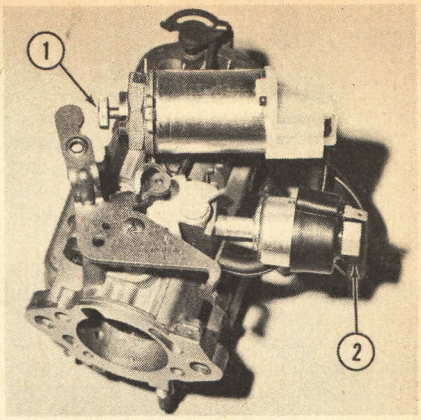
4. There's no normal throttle cracking screw on '72-'73 GM 6-cylinder engines. "Solenoid off" idle speed is set with an allen wrench in end of solenoid.

5. Pushing on the needle for any reason is verboten. The rubber tip of the needle can easily be compressed out of shape.

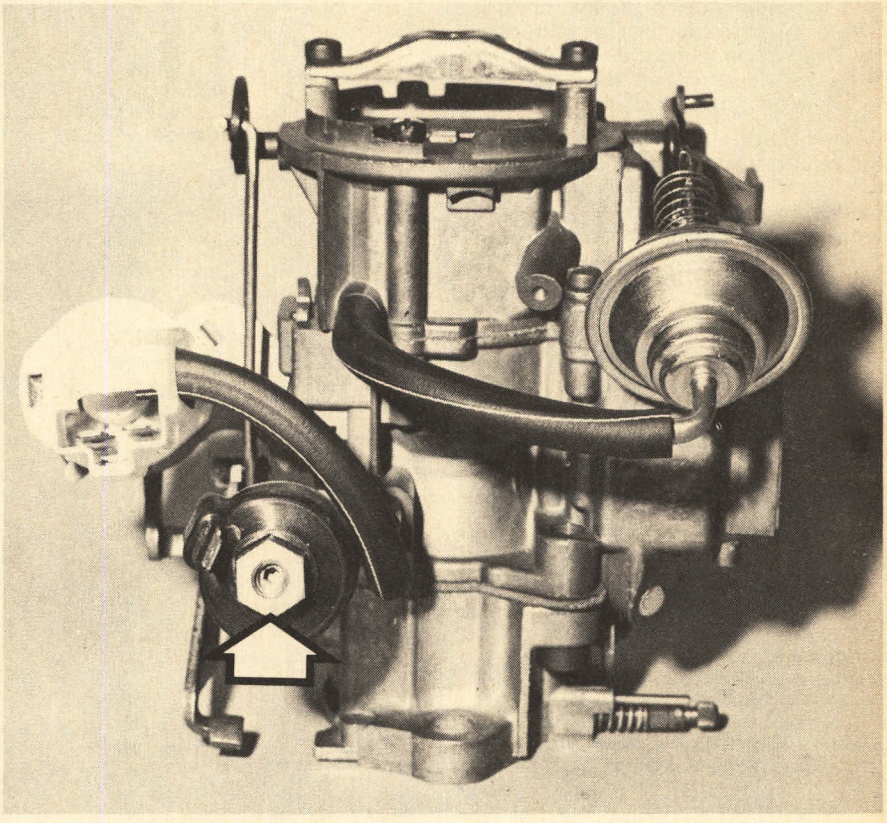
6. Fuel flows into the bowl past the needle whenever the float drops enough to let the needle come off the seat.



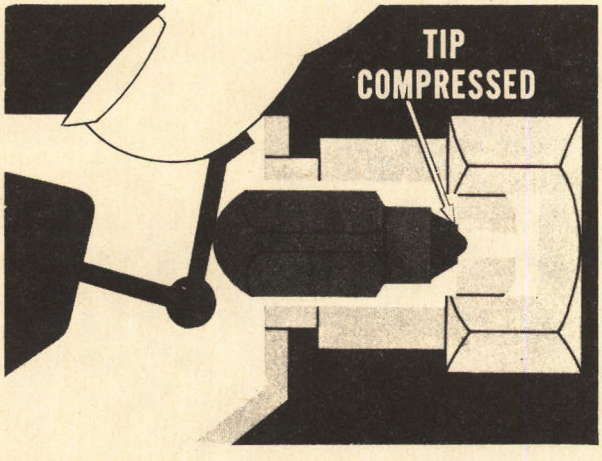
2. Buick Exhaust Gas Recirculator



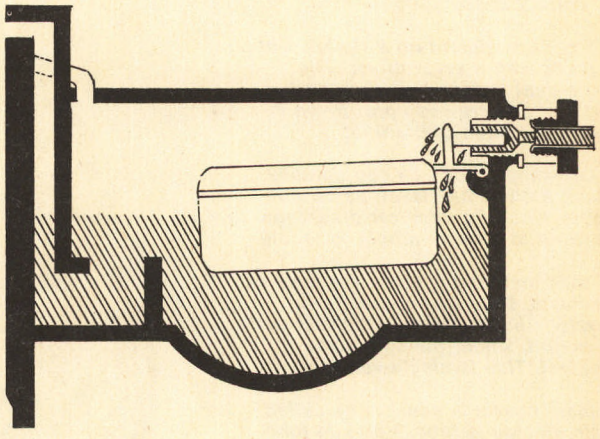
3. Rochester 6-Cyl. Carburetor



4. Low Speed Idle Adjustment



5. Don't Do This



6. Float System With Needle Open

Fuel System

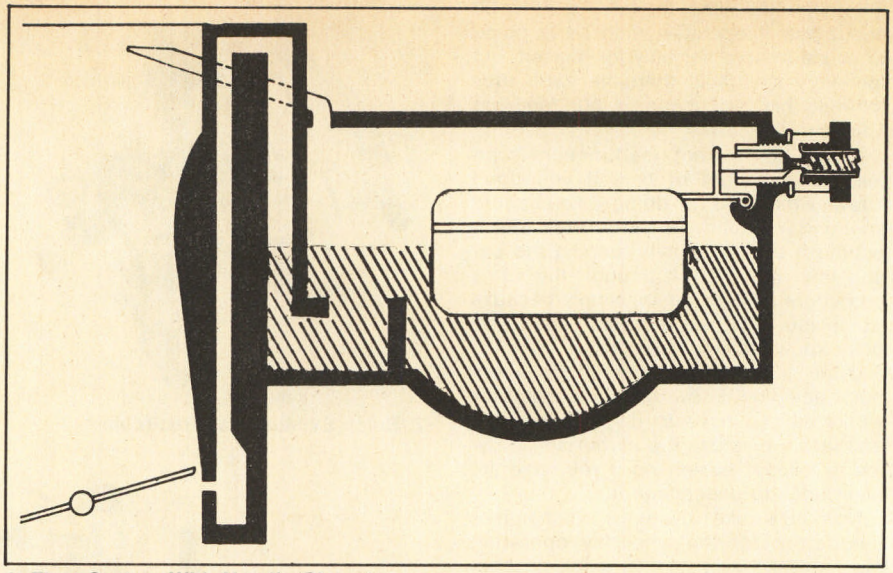
FLOAT SYSTEM

Fuel enters the carburetor through the inlet seat and fills the float bowl. The fuel rises in the bowl, lifting the float, which pushes the needle into the seat and regulates the flow of gasoline.

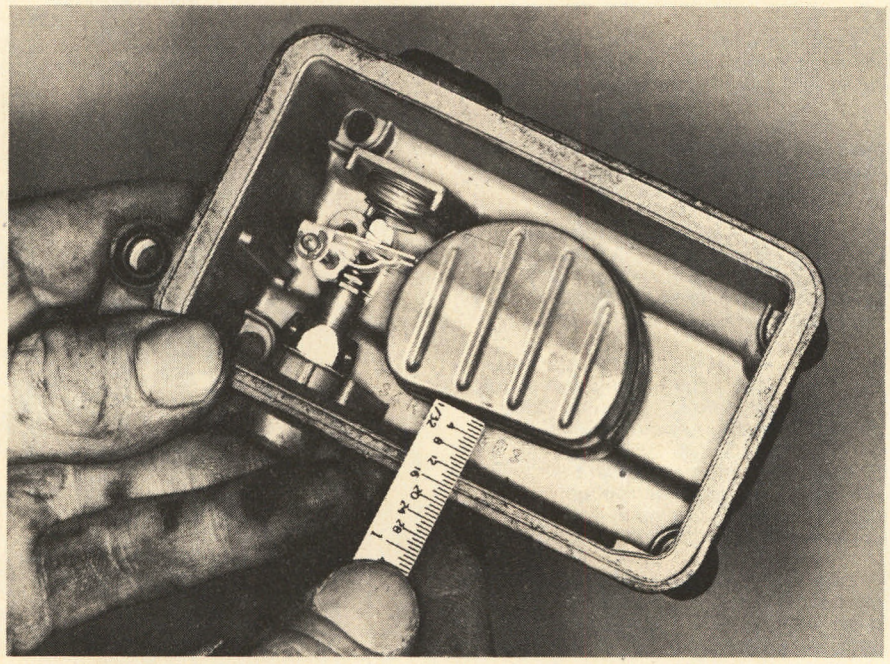
The object is to keep the fuel in the bowl at just the right level. Too much, and the engine will run rich. Too little fuel in the bowl and the engine will run lean, maybe even coughing back through the carburetor. Sometines the coughing back results in a flame that's about 3 ft. long shooting from the air horn. You only have to see that once to have a lot of respect for a carburetor that's being run without an air cleaner. At the very least you will make sure it's not pointed in your direction.

To adjust the fuel lever, you bend an arm on the float or bend a little tab that is attached to the arm and pushes on the needle. The "float level" specification is a measurement from some part of the carburetor casting to the float, when the float is resting on a closed needle. If the float is attached to the bowl cover then the measurement is taken between the float and cover, with the cover inverted so that the weight of the float closes the needle.

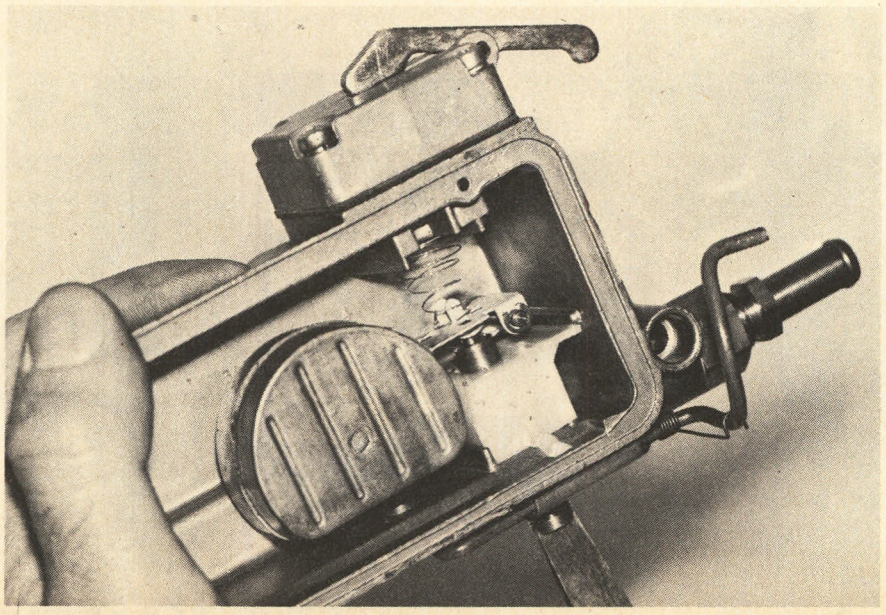
If the float is attached to the bowl itself then the measurement is taken from the top of the float to the top edge of the bowl, with the float and needle in the closed position, of course. To get the needle and float into the closed position on this type of float system, you might



1. Float System With Needle Closed



2. Checking Float Level



3. Adjusting Holley Float Level

1. Float system with a horizontal needle. A vertical needle works better. The tube at upper left is an internal bowl vent which raises pressure above the fuel when the engine is running at speed.

2. Float level is the only internal adjustment on a Holley. The measurement is made at the location shown, but it differs with other models of carburetors, so you should check your shop manual for correct specifications.

3. Float adjustment on a Holley 4-bbl. is made with a screwdriver. The entire seat assembly is threaded, and can be screwed up or down to change position of the float.

4. On some carbs you can actually check the wet fuel level, as on this Holley 1-bbl. Economizer diaphragm is removed to provide a hole for scale.

5. Main metering system has several functions. Note that end of main nozzle is in middle of narrowest part of venturi, where the suction is greatest. This is single-venturi carb.

6. Main nozzle is sometimes called main discharge tube. Holes in tube bleed air into fuel to help atomize it.

7. Suction in the venturi pulls fuel out of the nozzle. Actually, it's the pressure on the fuel in the bowl that pushes the fuel out of the nozzle.

push the float and needle closed with your finger—but don't

That was OK in the old days when we had steel needles, but now there are teflon-tipped needles, neoprene-tipped needles, and teflon or neoprene inlet seats. These needles and seats will last a long time with only the pressure of the float against them, but the pressure of your finger pushing on the needle may be too much, and you will end up with a groove in the neoprene. The neoprene will slowly come back to shape, eliminating the groove so that a few hours later the float level has changed from where you set it. If the neoprene or teflon does not come back to shape, the groove may cause flooding because it provides a place for particles of dirt to lodge.

To get the float and needle into the closed position on a carburetor with the float attached to the bowl, invert the carburetor and take the measurement. With the carburetor on the car, the easiest way to do it is to pour some gasoline into the bowl until the float rises to its maximum height, then take the measurement. There is usually a tolerance on float adjustments and a good mechanic will adjust to one end or the other of the tolerance because he knows a particular carburetor will run best with that setting.

It's important that you don't confuse fuel level and float level. Float level is a measurement from the float to some part of the carburetor bowl or the cover. Fuel level is an actual wet measurement of how far the fuel is from the top of the bowl. If the float needle and seat are attached to the bowl, then the actual fuel level can be measured with a scale. If the float needle and seat are attached to the bowl cover, then the fuel level cannot be measured in most cases unless the carburetor manufacturer has provided sight holes in the end of the bowl. The fuel level specification, if given, is really nothing more than a double check to be sure you have set the float level correctly and accurately.

When the engine uses fuel and the float drops, it is possible on some carburetors that the needle could fall out of the seat. If this happened the carburetor would receive just a little more gas than it needs. The engine would be flooded, not only on the inside but probably on the outside.

To keep all of that from happening there is a little tab on the back side of the float that limits the drop. The float drop measurement is taken with the bowl cover off the carburetor. Hold the cover in the normal position and measure from the underside of the bowl cover to the float.

If the float is attached to the bowl itself, there usually is no float drop measurement. The float in that case may be designed so that at maximum drop it rests on the bottom of the bowl.

If by some chance the little tab that limits float drop has become bent, then the float may not drop enough. In this case the needle will not pull away from the seat far enough, and you might have fuel starvation at wide open throttle.

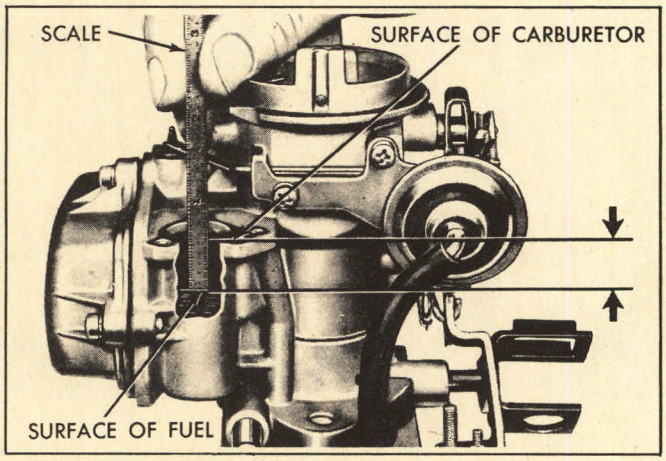
Dirt, as mentioned, is a big enemy of the float system. If it weren't for dirt there probably wouldn't be any need for all the fancy filters that we have on cars nowadays. The needle and seat are so sensitive to dirt that the smallest particle can cause flooding. This is the reason for using teflon or neoprene seats and needles. The theory is that teflon or neoprene has enough give to it that it will conform to the shape of the speck of dirt and seat around it. Sometimes it does, sometimes it doesn't.

If a particle of foreign matter should cause the needle valve to leak, then enough fuel can be pumped into the engine to kill it, and make restarting almost impossible until the excess fuel evaporates. If you ever see a carburetor that is all beat up around the needle and seat area, it's a good bet that the driver was standing there beating on the carburetor trying to jar a piece of dirt out of the seat so the flooding would stop.

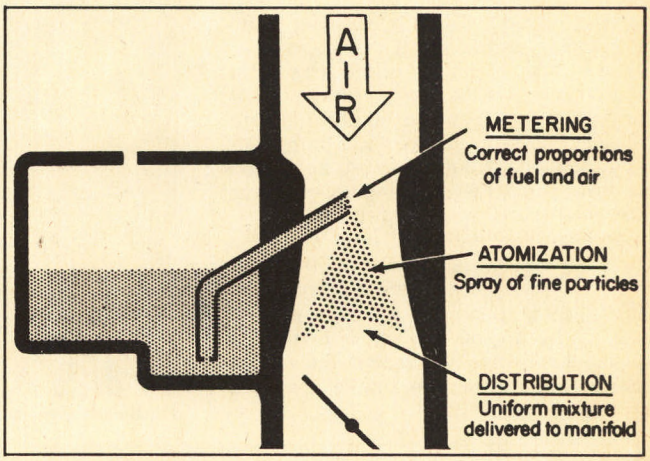
You can see that keeping the fuel at the right level is very important. We'll find out why when we go into the main metering system.

MAIN METERING SYSTEM

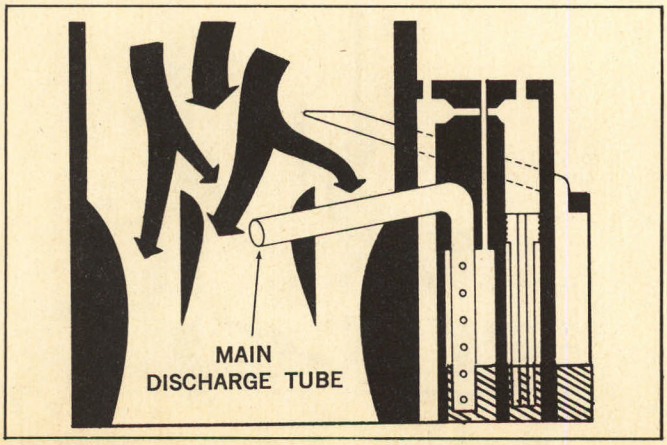
Now that we have the float bowl full of gasoline, the next step is to get this gas mixed with air and feed it into the engine. The base of every carburetor is really nothing more than an air valve with throttle plates hung on a shaft controlled by your foot. Wide open throttle means just that. When you step on the gas you are opening the throttle valve so that the



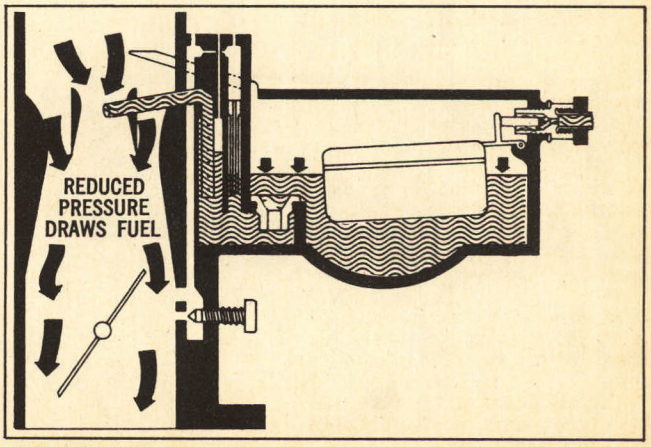
4. Checking Wet Fuel Level



5. Venturi Operation



6. Main Nozzle



7. Main Metering System

maximum amount of air can enter the engine. But in order for the engine to run, this air has to have gasoline mixed with it in the right proportion. This is done by running a tube from the float bowl ending in the middle of the air stream where it goes through the carburetor. The end of the tube, called the main nozzle, is positioned so that it is in the center of the venturi, a narrow section of the air passage through the carburetor. Because this section is narrow, it causes reduced pressure at the end of the tube, and this reduced pressure or suction draws fuel from the float bowl where it mixes with the air, then goes past the throttle valve and on to the combustion chamber. The tube begins in a well at the bottom of the float bowl called the main well. Fuel enters the main well through a calibrated hole called the main jet, which is located at the bottom of the float bowl so that during all types of engine operation it will always be submerged and able to draw fuel.

The main metering system has had many refinements since the first simple carburetor was made. There may be air bleeds or little baffles in the main nozzle and there may be vacuum or mechanically operated metering rods in the main jet. The object of all the refinements is to be sure that the engine receives more fuel when it needs it and less fuel when it doesn't.

Metering rods are designed so that they stay in the main jet when the engine is running at low power. But when the engine is running at maximum power, the rods will lift out of the jet so that the engine gets the fuel that it needs. At any point between closed throttle and maximum power, the rods will be partially in or partially out of the jet, according to how much fuel the engine needs at the time.

Mechanically operated rods are lifted by a lever hooked to the throttle. Vacuum-operated rods are pushed out of the jet by a spring and pulled down into the jet by engine vacuum acting on a piston hooked to the top of the rod. A passageway from the intake manifold runs up through the carburetor so the engine vacuum can act on the piston.

Without engine vacuum the carburetor wouldn't work. This vacuum exists below the throttle valves when the engine is running, and at idle on a good engine is about 18-21 ins. As the throttle is opened, engine vacuum drops off until there is zero vacuum at wide open.

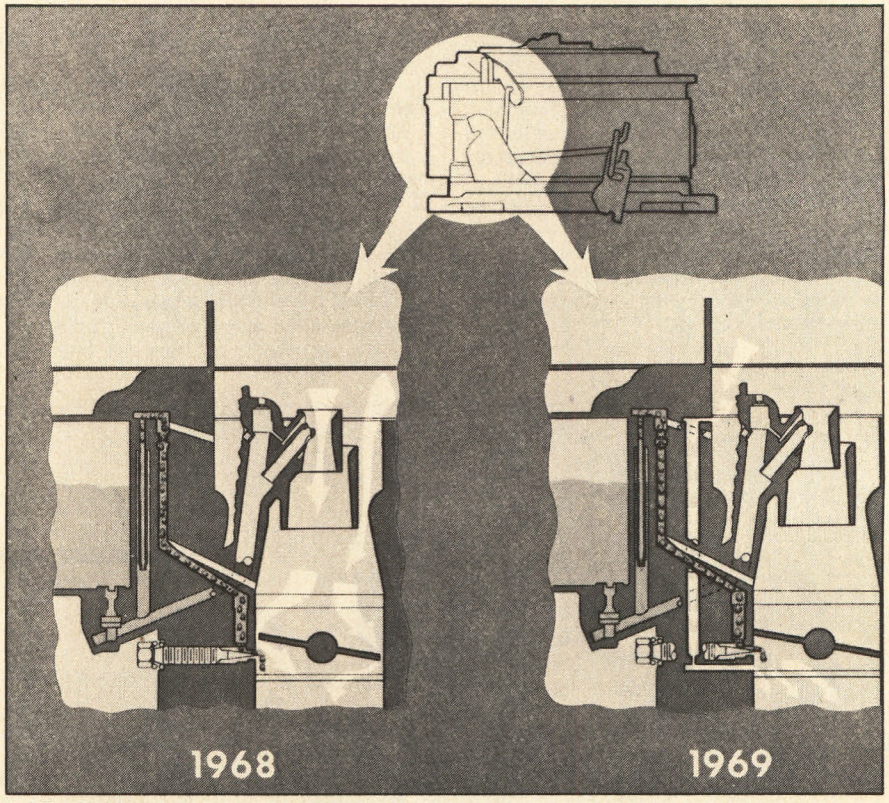
It's rare to have a main metering system plug up completely unless it was done deliberately for a test of mechanics, such as the Plymouth Trouble-Shooting Contest. If the main nozzle was plugged, but the main jet still open, the carburetor would idle perfectly, but gasp and die completely the second the throttle was opened. However, if the driver got his foot out of it quick enough, the idle system would take over again and the car would come down to idle perfectly.

We have to have an idle system, because at idle the throttle valves are almost completely closed and there is not enough flow of air through the venturi to draw fuel out of the main nozzle. Now let's see how the idle system does its job.

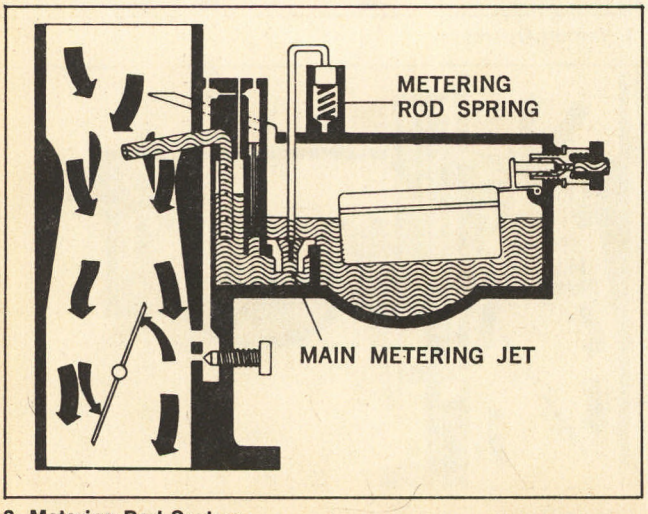
THE IDLE SYSTEM

At idle the engine is drawing air around the throttle plate, which is just barely open, but this air has no fuel in it. The fuel is coming through the idle port hole in the throttle body below the throttle plate. An idle mixture needle screws into the outside of the throttle body and is used to regulate the amount of fuel flowing through the port and into the engine.

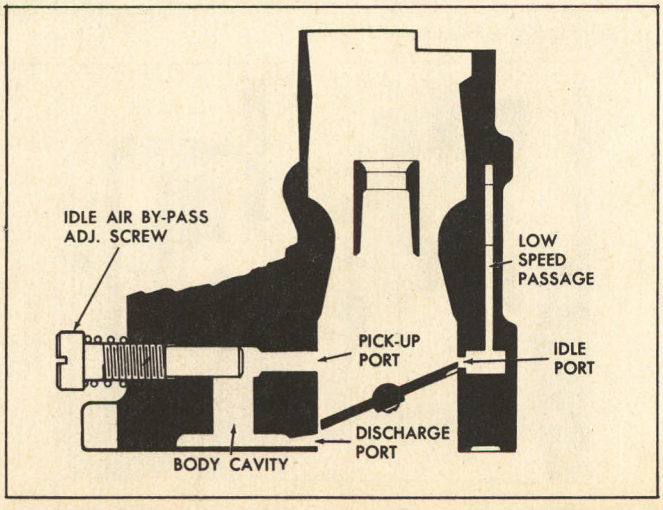
Fuel enters the idle system through a tube which is mounted in the carburetor,



1. Idle Air Bypass



2. Metering Rod System



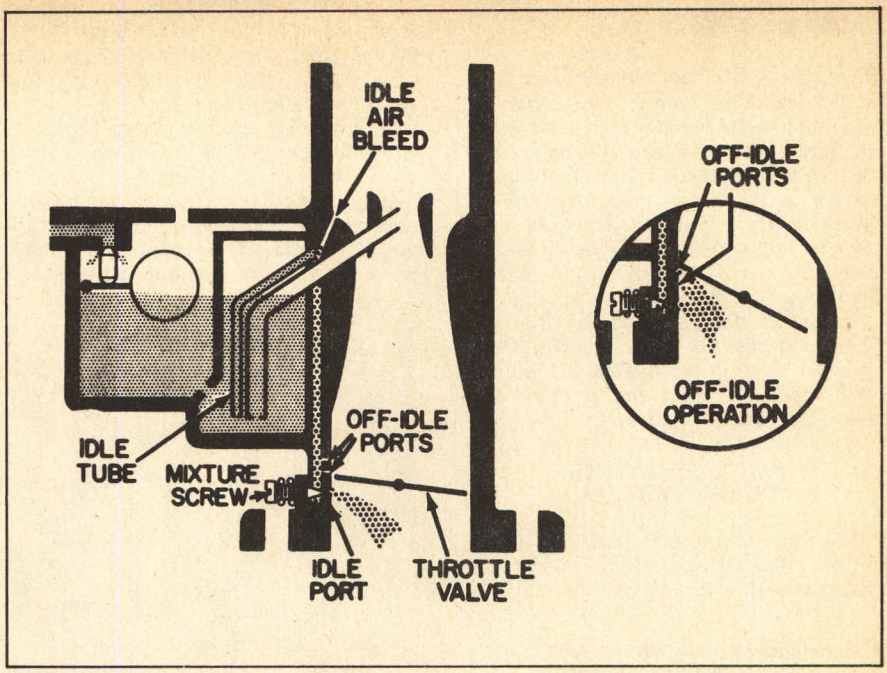
3. Adjustable Idle Air Bypass

usually between the float bowl and the carburetor throat. The end of the tube is a calibrated hole, called the idle jet. Fuel comes up through this tube, makes a U-turn, picks up some air through air bleed holes, then goes through a long passage to exit underneath the throttle plate. Some idle tubes can be changed merely by unscrewing them, but others are part of the metering cluster and the whole cluster must be changed in that case.

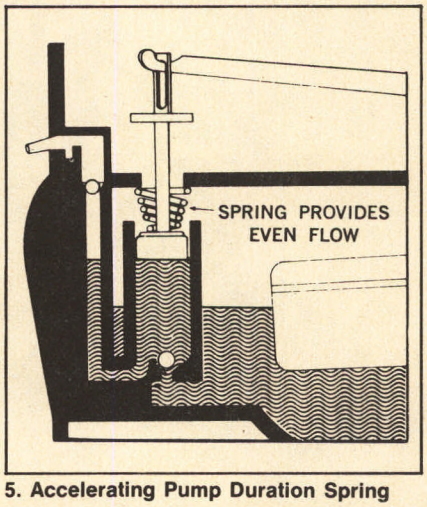
As the throttle is opened, the high vacuum beneath the throttle plates starts to fall off and fuel flow lessens through the idle port. To keep the engine from faltering at this crucial moment, another hole called the idle transfer is uncovered which feeds more fuel to keep the engine going. By this time enough air is coming through the venturi that the main metering system will start to take over. However, in most carburetors the idle system will continue to feed even up to as high as 70 mph.

It's important to keep clear in your mind that the engine idles on air from two sources and fuel from one. Air goes into the engine around the partially opened throttle plate, and a fuel and air mixture enters through the idle port, controlled by an idle mixture screw. The screw is spring-loaded, and you control the idle mixture by setting the screw.

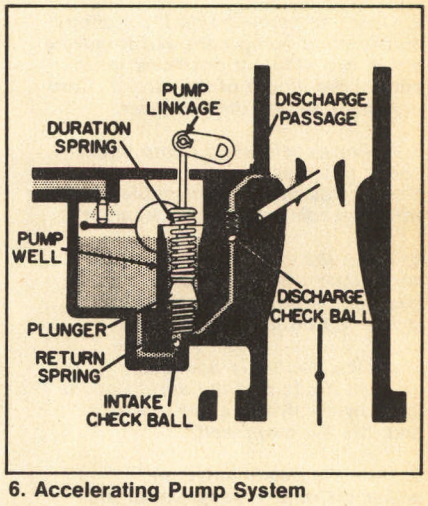
Engine idle speed is something else. You control that with a spring-loaded screw on the throttle shaft. When the



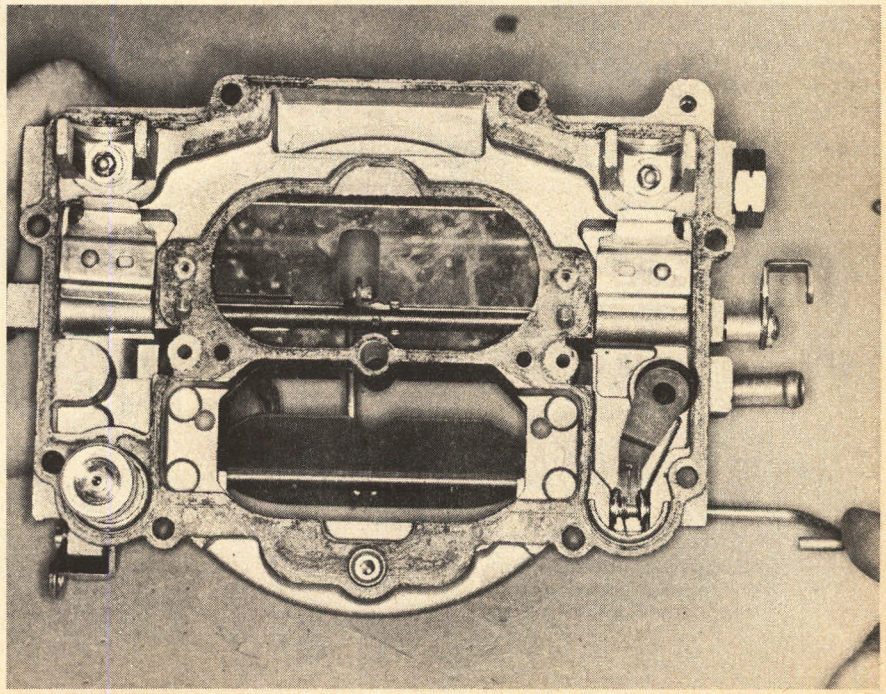
4. Idle System



5. Accelerating Pump Duration Spring



6. Accelerating Pump System



7. Bowl Vent Lever

1. In 1968, Oldsmobile used a Quadrajet that cracked the throttle plate for idle air. In 1969, they allowed the throttle plate to close completely, and idle air came through an adjustable bypass.

2. Metering rod is hooked to a piston and spring, with engine vacuum acting on the piston. Any fuel that flows out the main nozzle has to go through the main jet first.

3. If idle air is supplied through a bypass, the throttle plates can be allowed to close almost completely at idle. This helps to prevent carbon formation in the throttle bores, which causes erratic idling.

4. Note how the idle tube picks up fuel from within the main well. Some late-model carburetors designed for emission control have the idle tube outside the main well.

5. In this type of spring-operated accelerating pump, it doesn't matter how fast you step on the gas—the spring itself is what pushes the pump plunger down.

6. The "duration spring" is actually an override spring that prevents everything from bending if the driver shoves his foot down too fast. The discharge check ball usually has a spring or a weight to help prevent fuel from being drawn into the venturi at high speed.

7. Little lever opens the bowl vent whenever the throttle linkage is at the idle position. Bowl vent is really not part of idle system, but it prevents rich running at idle (and hard starting) by venting fumes.

driver takes his foot off the gas, the throttle will close down to the setting you have made with the idle speed screw. If you have made the wrong setting and the throttle closes too much, the engine will die. If the screw holds the throttle open too far, then the driver is going to have to put both feet on the brake to keep the car from driving down the street at a 40-mph idle speed.

So far, we have a carburetor that will cruise and idle, but what happens when we really step on the gas? It will fall flat on its face. To cure the problem we need an accelerating pump.

ACCELERATING PUMP SYSTEM

If we open the throttle suddenly on an engine, the air reacts instantly and rushes past the throttle blades, but the fuel coming out of the main nozzle takes a little while before it catches up. During this period the engine will run lean and stumble. The problem is solved by using an accelerating pump. It's nothing more than a piston hooked to the throttle linkage and operating in a cylinder so that every time we step on the gas a squirt of fuel goes into each throat on the carburetor. The pump only squirts when the throttle is moved. At all other times it does not feed any gas but just sits there waiting until the time when you put your foot down.

The pump system includes an inlet check valve and an outlet check valve so that it can suck fuel into its cylinder from the bowl on the upstroke and then squirt this fuel into the carburetor throat on the downstroke.

Some pumps are not directly operated by the throttle linkage but *allowed* to operate by the linkage. They have a duration spring that actually pushes the

1. Accelerating pump on the AFB is adjusted for more or less stroke by bending the pump link.

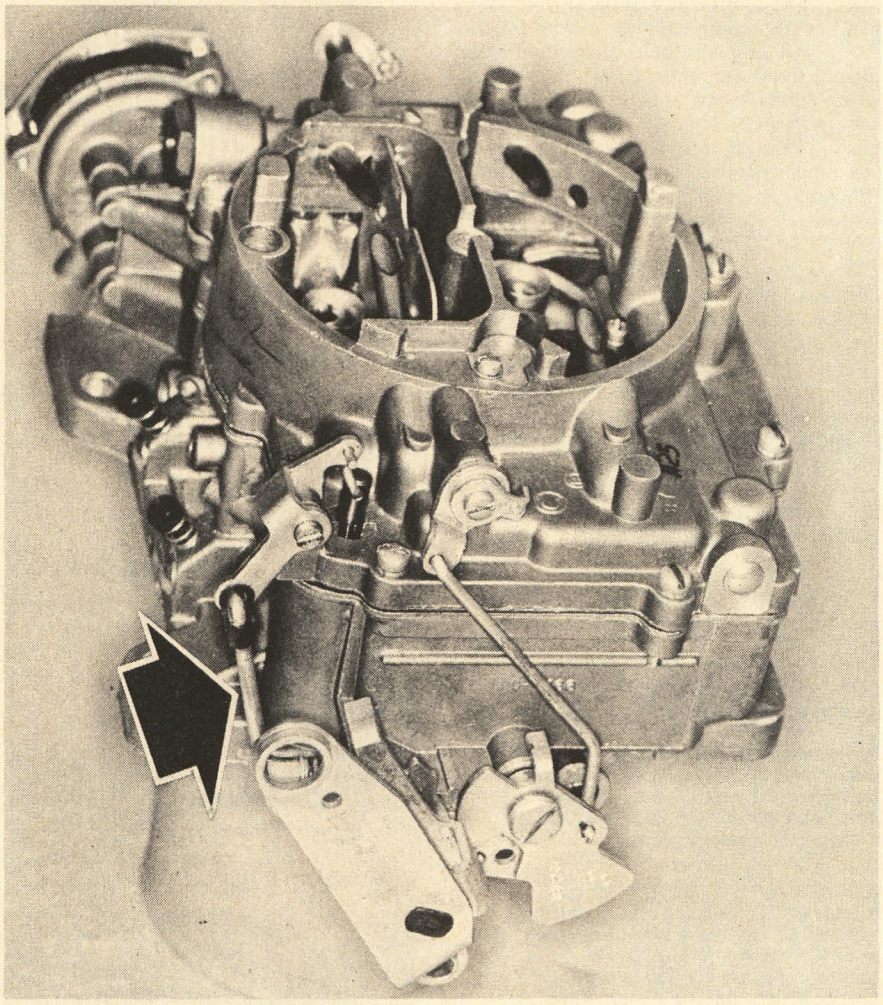
2. Only one screw holds the Holley accelerating pump cam, but it can be put in two different positions to control the length of the stroke. Cam is hidden behind throttle lever.

3. Holley accelerating pump outlet check is under the pump nozzle. Many carbs have a removable nozzle with a needle or ball check under it.

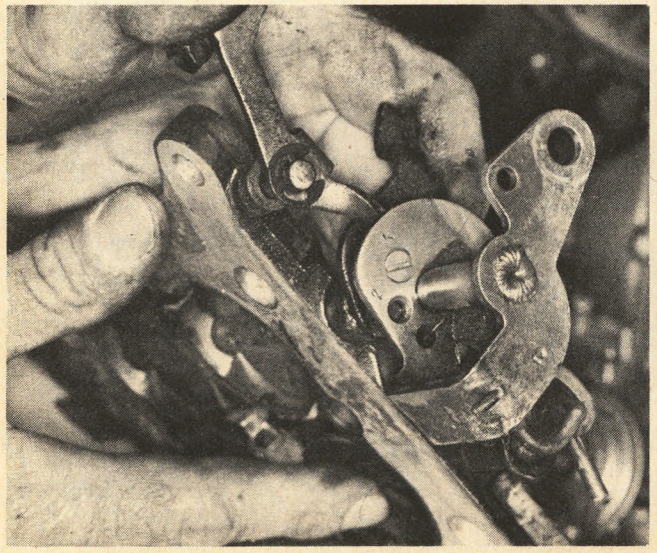
4. When manifold vacuum is high and during closed or partly closed throttle, the power valve piston is held up off the valve.

5. As the throttle is opened, vacuum drops and the spring opens the power valve to allow extra fuel into the main well.

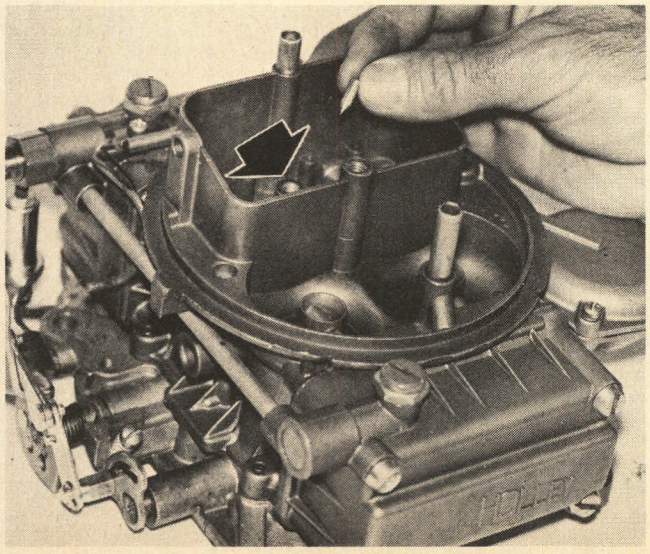
6. Here the power valve and power piston are separate. In the power valve the top hole that the plunger sticks through is merely the entrance for the fuel. The calibrated holes are the ones on the side just above the threads.



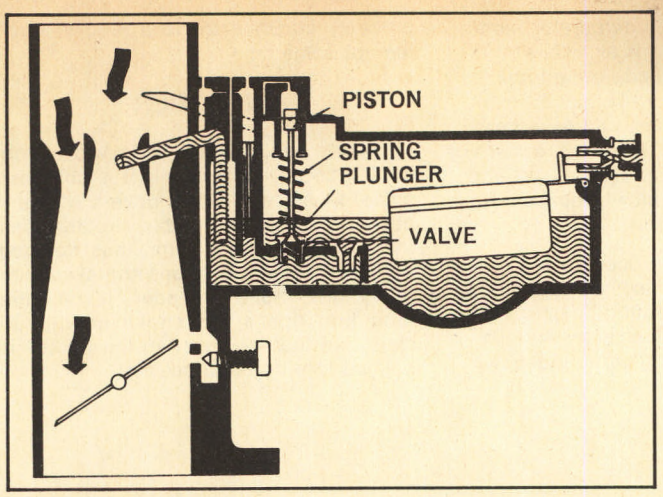
1. Pump Arm Adjustment



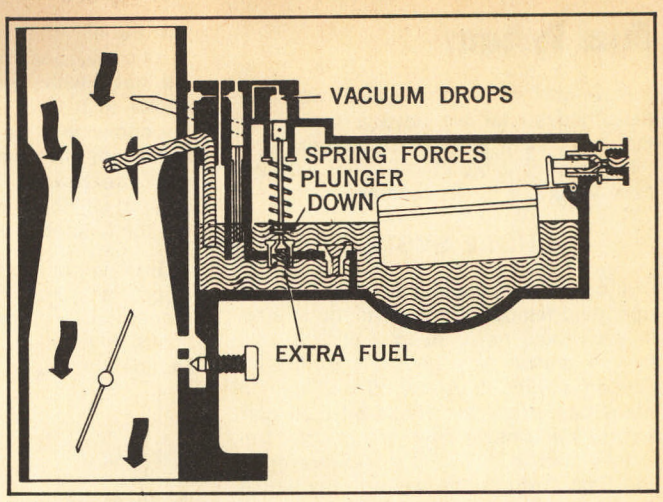
2. Holley Pump Cam Adjustment



3. Holley Pump Check Valve



4. Power Valve Closed



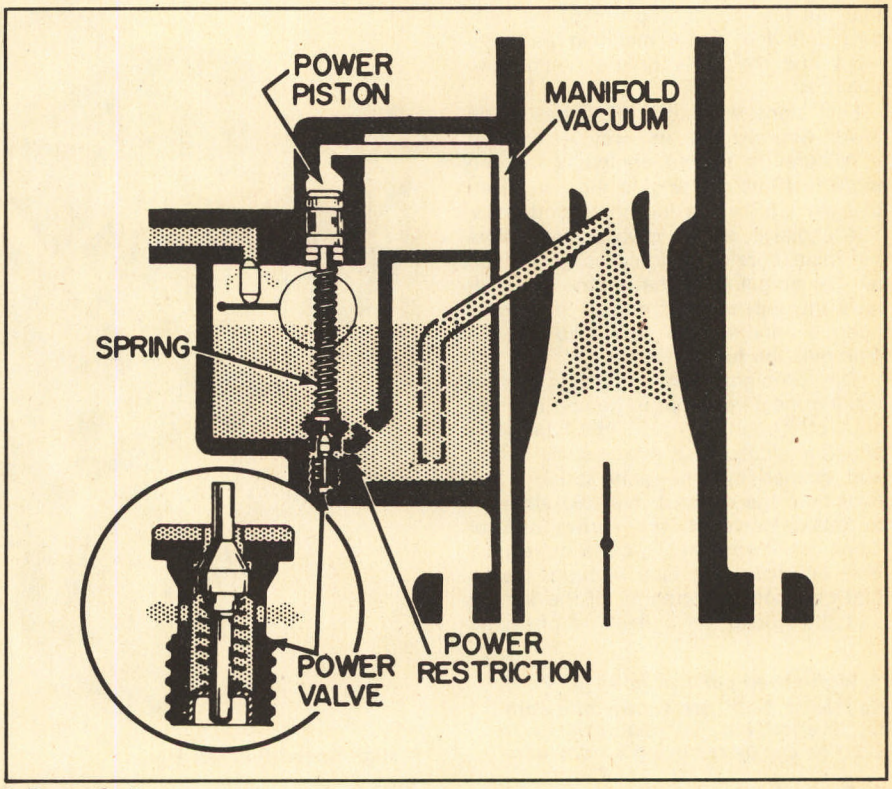
5. Power Valve Open

pump down. This is done so that the length of time that the pump is operating is always the same, no matter how fast the driver opens the throttle.

The well known "flat spot" on acceleration is usually caused by something wrong in the accelerating pump. Most of the time it is a pump piston that doesn't fit well in its cylinder, either because the piston is worn out or because it is made of leather and the lip of the leather curled up when the piston was installed. Or it could be maladjusted linkage, so that the pump stroke is too long or too short.

The jet that controls the amount of squirt on an accelerating pump is usually built into the pump nozzle, mounted above the venturi. In an extreme case, that defies the best efforts to correct the trouble, it is possible to drill out the pump jet for a little more squirt, so you won't have that sickening feeling of nothing happening when you mash your foot down to the floor.

With the system so far described, our carburetor will work fine, until we get up to wide open throttle. Then the engine needs more fuel than is admitted by the main jet. To let this fuel in we must have what is called the power system.



6. Power System

POWER SYSTEM

Main metering jets with or without metering rods work fine above idle at almost any cruising speed but when the engine is really called to put out, with the throttle wide open, the main jet just doesn't let enough fuel in. In order to admit more fuel, there is another passage into the main well and up into the main nozzle. This passage is closed at all times except when the throttle is opened enough to allow engine vacuum to fall below about 10 ins. At that point a spring opens the power valve and additional fuel is allowed to enter the main well, go through the main nozzle and into the venturi.

Power valves can be vacuum or mechanically controlled. Some Stromberg carburetors have the power valve at the bottom of the accelerating pump cylinder so that when the throttle is open wide and the accelerating pump bottoms, it tips a little plunger opening the power valve. Other power valves operate off engine vacuum opposed by a spring, and they can be either a piston operating in a cylinder or a diaphragm.

The unfortunate thing about a power valve is that you may not know if it is bad until it is too late. If a power valve should fail in the closed position, the engine would not get the fuel it needs at wide-open throttle, and it might even run lean enough to burn a hole in a piston, depending on how long you ran the engine wide open.

Luckily, vacuum-operated power valves are held closed by engine vacuum, and opened by a spring. So if they fail, they usually fail open, allowing a lot of fuel to go into the engine at all speeds above idle, and in some designs even allowing fuel to dribble out onto the top of the engine, which is good if the driver pays attention to the smell of gasoline. Of course it's not so good if somebody starts lighting matches in your engine compartment.

HIGH SPEED PULLOVER

Main jets must be lean on late models to cut down on emissions. Unfortunately, the main system is so lean that there isn't enough fuel supplied under a high-rpm, part-throttle condition. At part throttle, the metering rod hasn't lifted to the high speed step because engine vacuum hasn't dropped low enough. But the engine needs more fuel because of the high rpm. Rochester carburetors provide this extra fuel with a pullover system, which consists of a passageway from the float bowl up to the air horn, exiting above the choke valve. There is usually one hole for each carburetor throat. Because of their position, these holes are sensitive to air velocity. Any time there is high air velocity through the carburetor, as at high rpm, the pullover holes feed additional fuel into the airstream. Pullover starts at about 50 mph on part throttle. Pullover is also called High Speed Fuel Feed, or Auxiliary Fuel Feed.

Fuel System

Now with all of the systems we have described so far we have a carburetor that will really run. There is only one thing wrong, it won't start. For this we have to have a choke system.

CHOKE SYSTEM

If an engine could be heated up to operating temperature before you started it, you would never need a choke. This is one reason why people who live in California with its warm climate can in many cases take the choke off their carburetors and never have any trouble. But if they had to live in the Midwest or in the East through one winter, they would find out just what a choke is for.

A cold engine is just that. It is so cold that the fuel condenses out of the mixture onto the intake manifold passageways and the walls of the combustion chamber.

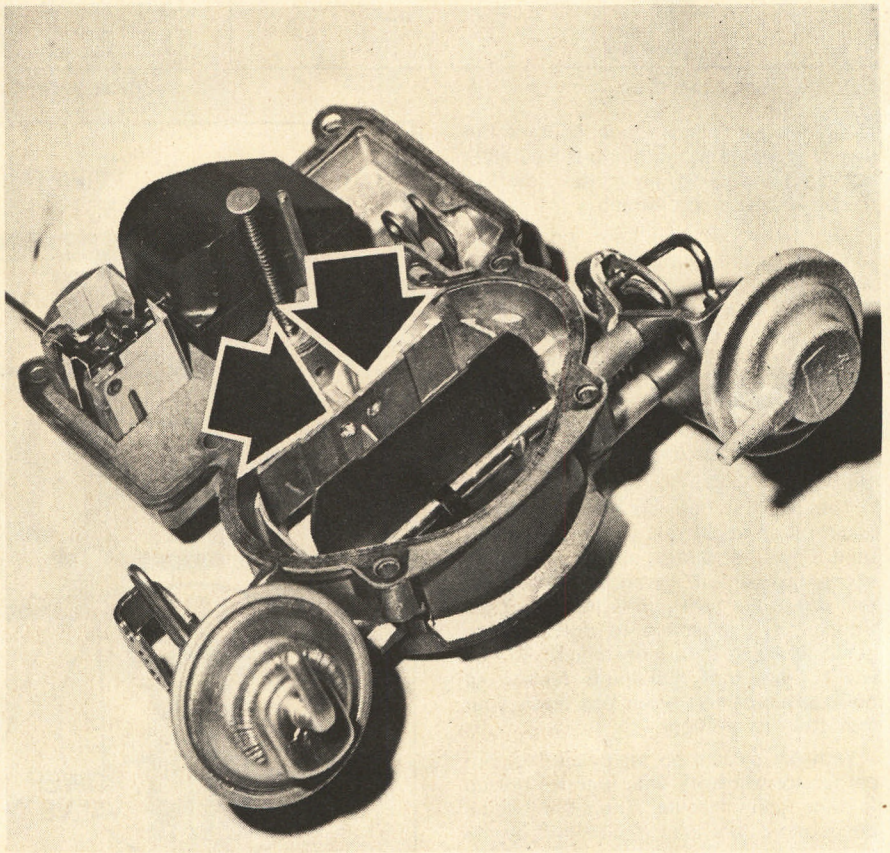
Fuel alone will not burn. It has to be mixed with air. The only way we can get a mixture on a cold engine is to feed more fuel into the engine than we need to make up for the fuel that condenses. The choke is an air valve placed above the main nozzle, so that it can shut off all the air going to the engine. This allows the full force of engine suction to operate on the main nozzle so the engine gets the fuel it needs.

The problem with chokes is not in making them work but in getting them to shut off (open) at the right time. The choke is closed by a thermostatic spring and opened by this same spring when heat from the exhaust manifold allows it to relax. However, the spring control alone is not enough. To get a more positive control there is a vacuum piston that opposes the strength of the spring, and the choke valve itself is offset so that the air entering the carburetor tends to push it open. When it all works right we have what is called an automatic choke, instead of the old fashioned manual choke that the driver had to remember to open himself. When it doesn't work we have a big problem, and the engine will lope and blow black smoke out the tailpipe.

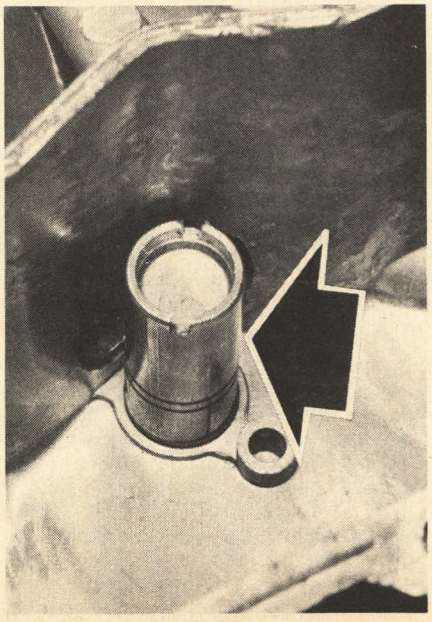
Sticking chokes have been so much of a problem that now some carburetor manufacturers are coating their choke shafts with teflon. It seems to work, although the adjustment of a choke will probably continue to be a touchy problem for some time.

UNLOADER

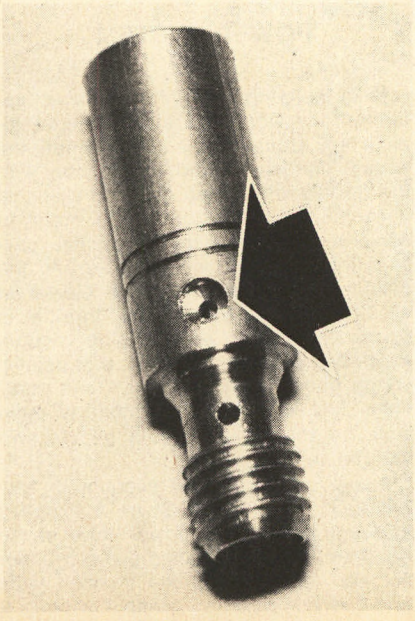
Nobody should ever go to wide open throttle on an engine while it is cold, but some drivers will. Other drivers will very absentmindedly pump the throttle when trying to start the engine, thus flooding it. Both of these conditions are taken care of by the choke unloader. It's a little tang that opens the choke enough to clean out the engine when the throttle is pushed to wide open position.



1. High-Speed Pullover Holes



2. Gravity Power Valve.



3. Power Valve Metering Hole

1. High-speed pullover holes in '72 Rochester 2-bbl. are shown with carb top inverted, but they can easily be seen on car by removing air cleaner.

2. Rochester 2-bbl. carbs used on Vega in '71 and later had a different power valve: gravity operated; no springs, just a weighted needle. Early models had metering passage built into carb.

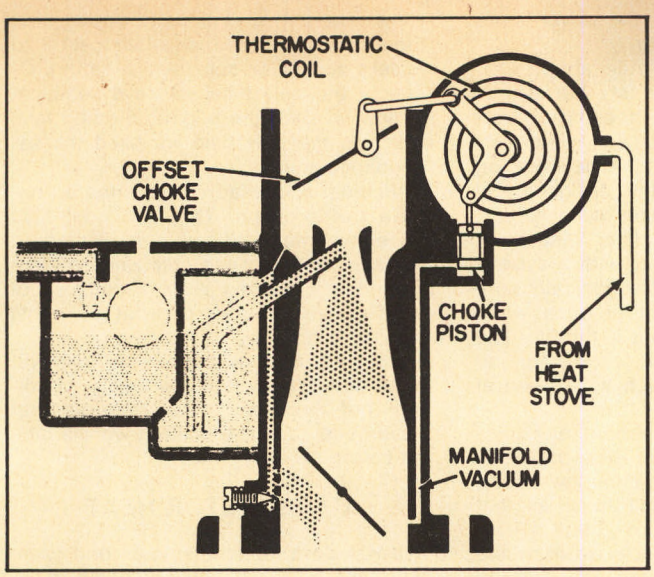
3. Late Vega 2-bbls. use power valve with metering at inlet orifice. Shake valve and you can hear weight rattle.

4. The choke system is a balancing of forces. The offset choke valve, the vacuum piston, and the heat from the stove all tend to open the choke, while the thermostatic coil spring is attempting to close it.

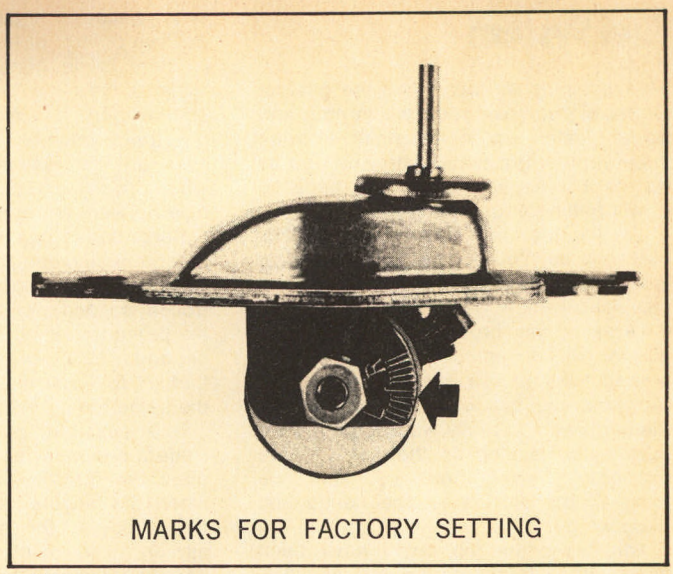
5. Well-type chokes do have an adjustment, but it is usually only a setting made at the factory.

6. Exposed spring on Rochester carbs is choke closing assist spring. It ensures full closing of the choke.

7. Choke springs are getting extremely sophisticated. Hidden under this cap (arrow) is a bucking spring (2-bbl. GM models) that works against choke coil spring for precise choke opening.



4. Choke System



5. Well-Type Choke

FAST IDLE

While the choke is operating, the engine can't use the extremely rich mixture unless it is run at a faster than normal idle. To accomplish this we have a fast idle cam and linkage that works in conjunction with the choke to raise the idle speed any time the choke is operating.

MULTIPLE BARREL CARBS

All of the systems described so far have pertained to a carburetor in its simplest form, but we haven't said anything about the number of barrels or throats on the carburetor.

Most engines from one cylinder up to six cylinders have a carburetor with only one throat. In that case there is only one of each carburetor system. Some 6-cylinder and some V-8 engines come with a 2-throat carburetor. In that case, the main metering system and the idle system are duplicated for the second throat.

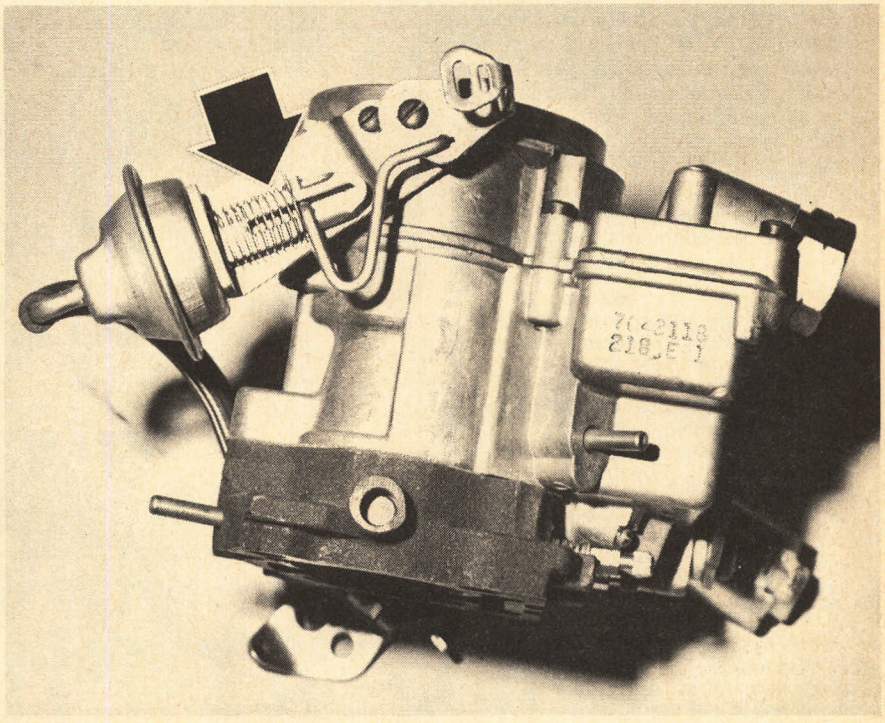
The float system does not have to be duplicated because the bowl has enough fuel capacity to serve two main jets with ease. The same reasoning applies in the accelerating pump system. One pump is used, but it has two nozzles, one for each throat.

The power system also stays basically the same as in a 1-bbl. carb, except that it feeds two main metering systems instead of one. In the choke department there isn't much change either; they just make the choke valve big enough to cover both carburetor throats.

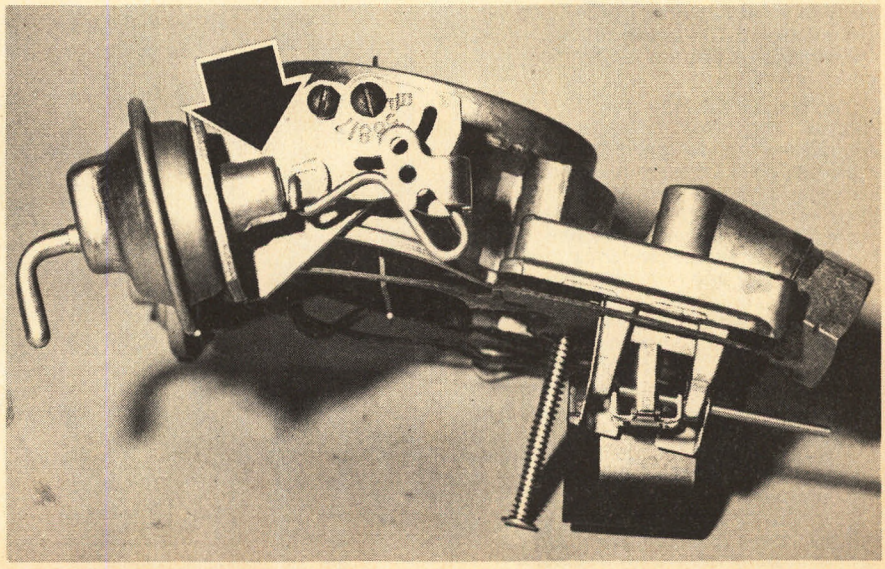
When we go beyond two barrels, however, there are some real differences. In a 4-bbl. carburetor the two barrels that the engine runs on normally are called the primaries. The extra two barrels only operate at high engine speed, when most needed.

As mentioned before, the carburetor is really nothing more than an air valve. At idle the air valve or throttle is closed because the engine doesn't need much air. As the engine goes faster it needs more air, or we might say that if the engine gets more air it will go faster.

At low speeds around town only a small throttle opening is needed to make



6. Rochester Choke Assist Spring



7. Rochester Bucking Spring

the engine do its job. When we get out on the highway we open the throttle and we go faster, up to the point of wide open throttle. But the engine won't go as fast as it is capable of running because it isn't getting enough air.

It's like the nozzle on the end of a garden hose. You open it up all the way, but you still don't get enough water. The only solution is to get a bigger nozzle.

To solve this problem the 4-bbl. carburetor was invented. The engine runs around town at low speeds on the primary barrels, but when we get out on the highway and really want to go, all we have to do is step on the gas and the secondary barrels open up. Then we have all the air the engine needs and away we go.

Admittedly, the job could have been done with a larger carburetor, eliminating all the complicated vacuum and mechanical controls that operate secondaries, but in that case there is a problem with driver education. An engine needs just the right amount of air to do its job. With a large carburetor the driver has to have an educated foot, and open the throttle just the right amount so that the engine doesn't get so much air that it gasps and wheezes. A 4-bbl. with primaries and secondaries is the only answer, because it gives the driver more positive control of his car.

There is no general rule about what systems feed the secondary barrels. Of course there is a main metering system, but there may be a power system or even an idle system. It all depends on what problems faced the designer and how he went about solving them.

Secondaries can be either vacuum or mechanically controlled, with maybe a velocity valve to boot. Mechanically controlled secondaries start to open when the primaries reach about ¾ throttle. The secondaries open at a faster rate, so that all four barrels reach wide open at the same time.

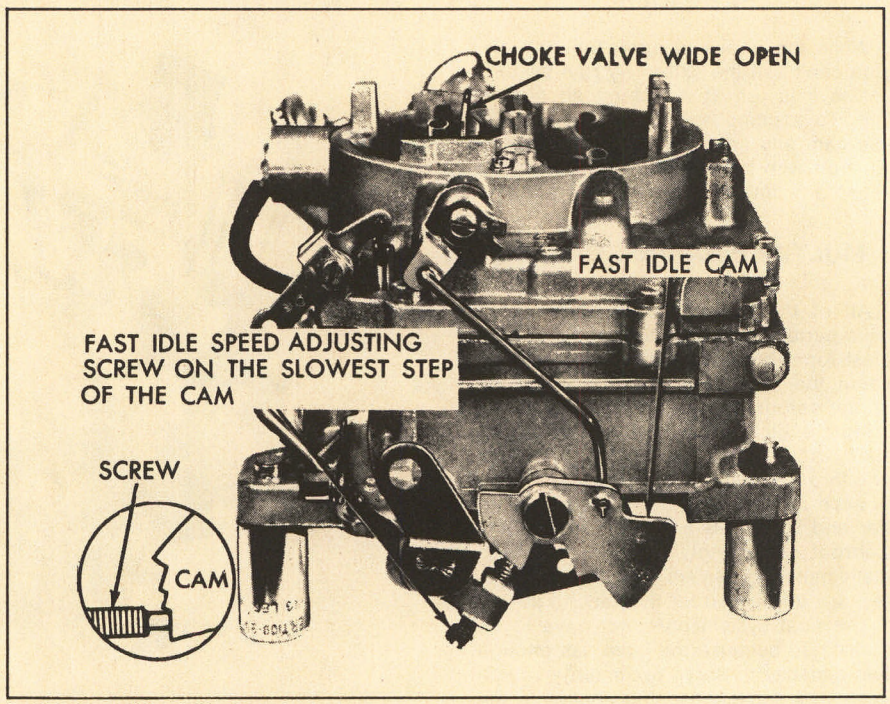
It is possible, on mechanically controlled secondaries, for the driver to open the throttle wide at a low speed when the engine doesn't need all that air. To correct this mistake, there is usually an air valve or velocity valve in the secondary barrels above the throttle valve. The air valve does not open until there is a sufficient rush of air past it to raise a weight or compress a spring. Of course the only time we have sufficient airflow is when the engine is going fast, which is the only time we need the secondaries anyway.

Vacuum-controlled secondaries do not have this problem. They are controlled by either manifold vacuum or venturi vacuum, so they open only when the engine needs the extra air, regardless of what the driver does or what he wants the car to do.

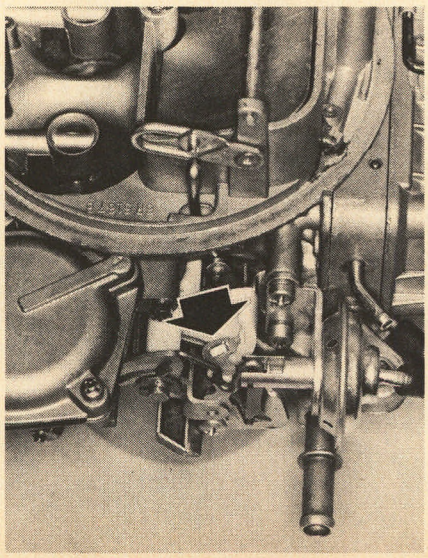
Now we have a carburetor that will work under just about any engine condition but there are other features that have been added to make it work a little bit better.

CARBURETOR HEAT

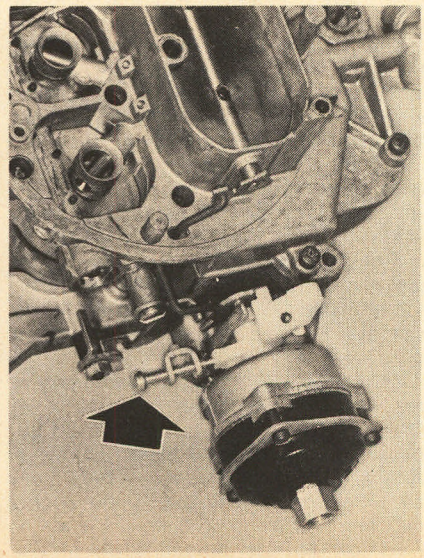
If you do a lot of driving around town, you need a heated intake manifold to im-



1. AFB Fast Idle Adjustment



2. Holley Fast Idle Adjustment



3. Autolite Fast Idle Screw

1. With the engine at normal operating temperature and curb idle, the cam is placed in this position to set the fast idle speed to the specified rpm. Specifications and adjusting techniques vary on every carburetor, so be sure you work from the right instruction sheet.

2. Holley 4-bbl. fast idle is adjusted by bending this little arm that rests on the fast idle cam.

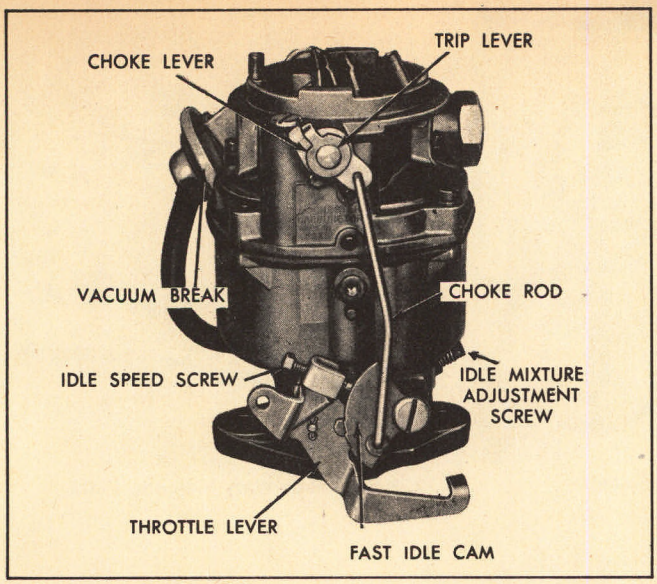
3. Screw at arrow on the 4300 is for fast idle adjustment only.

4. On this Rochester BV, as on some other carburetors, there is no separate fast idle screw. If the idle speed screw is set correctly, then the fast idle cam will determine the fast idle speed, providing the choke rod has been set to specifications. The choke rod is shortened or legthened by bending.

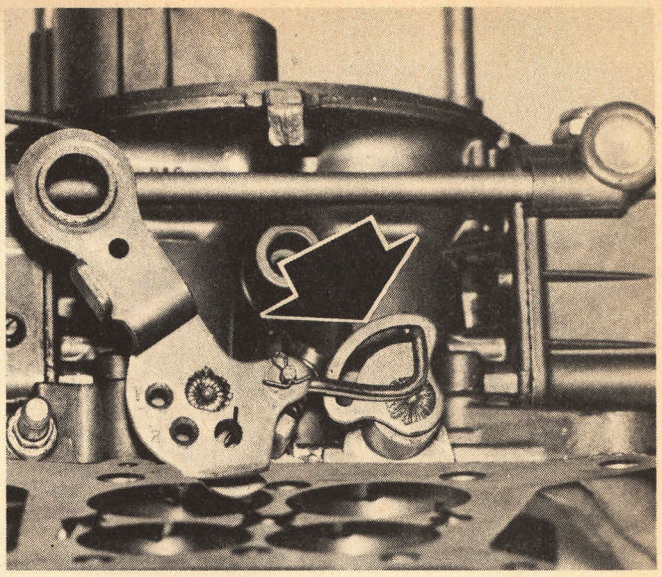
5. The famous (or infamous) link and slot on the Holley 4-barrel. It's a safety feature, designed to positively close the vacuum-operated secondaries if they should stick open. Accessory manufacturers have made all kinds of gadgets to link the primaries and secondaries together, using this slot and removing the vacuum diaphragm (or creating a leak so it doesn't work). Some of the gadgets don't work very well.

6. Holley 4150 has a thick metering block between the bowl and the main body on each side of the carb. This model has fully mechanical secondaries, with a separate accelerating pump for both primary and secondary.

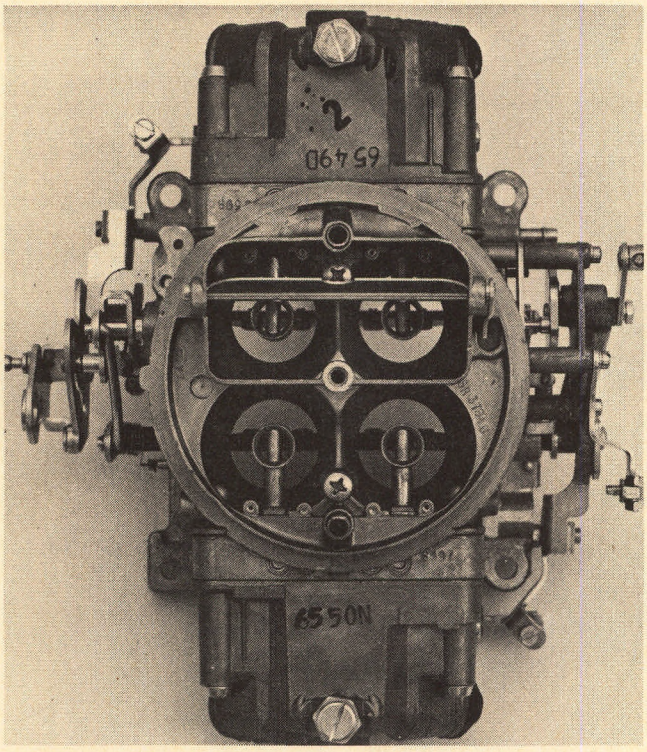
7. This slotted machine screw goes in this position only, when replacing the bowl cover on the 4300.



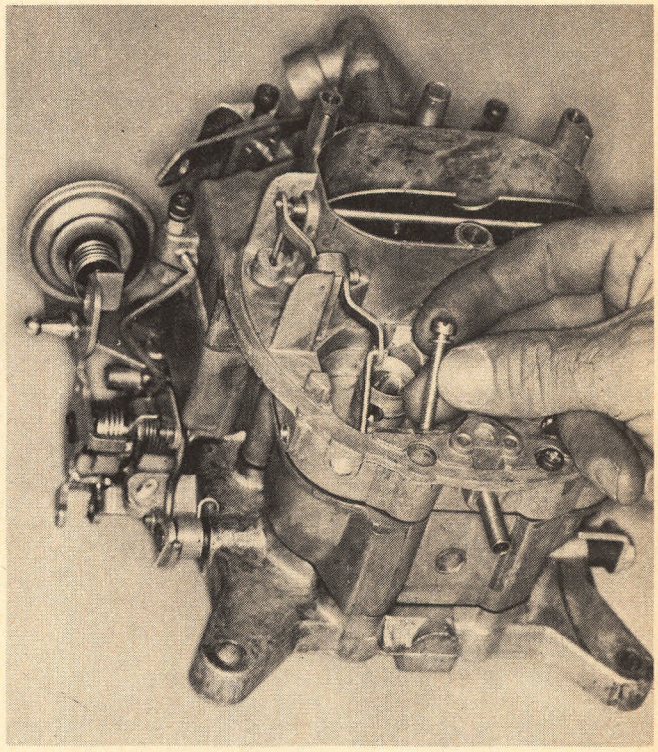
4. Rochester BV Fast Idle



5. Holley Secondary Link



6. Holley 4150



7. Autolite Special Bowl Screw

prove the low-end response. At a low speed the fuel mixture is moving slowly through the intake passages, and droplets of fuel have a tendency to fall out of the airstream. A heated manifold helps to keep the fuel vaporized. Heat comes from the exhaust gases which are usually channeled in some way so that they go up under the base of the carburetor to heat the intake passages. However, we do not want the fuel in the carburetor bowl to become heated, just the intake passages themselves. So you may find carburetors that are installed on their manifolds with a large insulating block or extra thick gasket.

ANTI-STALL DASHPOT

If you step on the throttle hard to go across an intersection, and all of a sudden you decide, because of the sudden appearance of a large object such as an 18-wheel truck, that it would be a good idea to stop, your engine may die when you take your foot off the throttle, unless it has an anti-stall dashpot, also known as a slow-closing throttle dashpot. The engine dies because you have already started a big load of fuel on the way to the cylinders but when you take your foot off the throttle, you shut off the air supply. The large load of fuel then floods the cylinders and kills the engine. An anti-stall dashpot stops this by holding the throttle open for a few seconds and allowing it to come down to idle slowly, which gives enough time for the engine to burn off the rich mixture.

By now you should have a pretty good idea of how the carburetor works. So let's go into a little troubleshooting and some of the repair procedures that you may have to perform.

IDLE MIXTURE ADJUSTMENT

One of the oldest tests in the world for finding out if a carburetor is operating correctly, is to make an attempt to adjust the idle mixture needles. If possible, mixture needles should always be adjusted with the fingers. If it is necessary to use a screwdriver because you can't get to the needles with your fingers, be very careful that you do not screw the needles in so far that you force them into the idle port hole. If you do this you will either put a ridge on the needle or may even break off the end of it.

Idle mixture is adjusted by screwing the needles in for a leaner mixture or out for a richer mixture. The usual setting at which almost any pre-smog engine will idle is 1½ to 2 turns unscrewed from the completely closed position. Late-model emission control carburetors

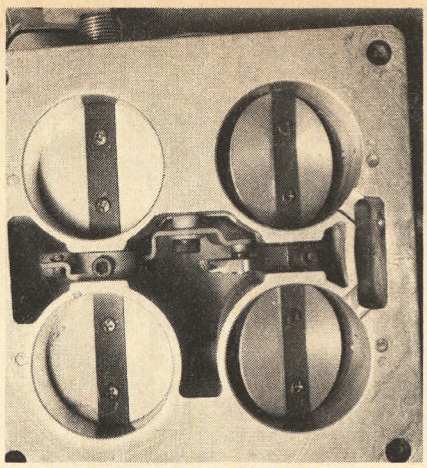
may require 3 turns before they will keep running. When you adjust idle mixture, the engine must be at operating temperature. The choke must be off and the fast idle cam must not be holding the throttle open.

Many other things must be checked before you actually set the idle. In some cars the headlights must be on so that the alternator puts a load on the engine. Some cars are adjusted in drive, some in neutral. Get the correct specifications for the car you are working on and be sure that you follow them to the letter. When the engine conditions are the way they should be, then it's OK to go ahead with the actual idle speed and mixture adjustment.

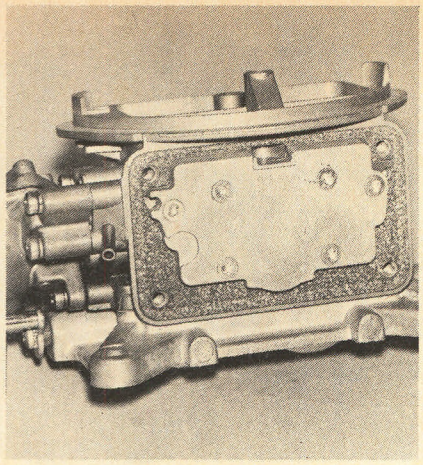
Screw one idle needle in slowly and you should notice a point where the mixture becomes so lean that the engine starts to falter. This is called the lean roll point or sometimes the lean fall-off point.

Unscrew the needle and you should notice a point where the mixture becomes so rich that the engine starts to roll; this is called the rich fall-off point.

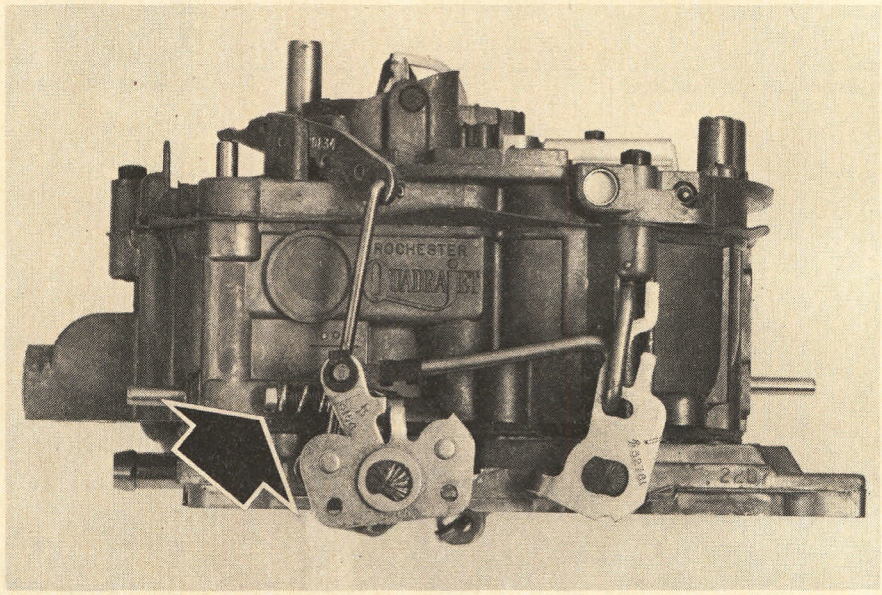
Late models run so lean that these points can be very hard to detect. On pre-smog carburetors, the usual setting for an idle needle is midway between the two points, or a little bit toward the lean side for better mileage. On emission control carbs we deliberately adjust for a poor idle, screwing the needles in (leaner) until the rpm drops by a specified amount. This is the only way that a late-model car will pass the idle emission test. However, if done exactly according to your factory shop manual, the idle will not be bad enough to bother you, and the air will be a heck of a lot cleaner. An exception to the rpm-drop method is



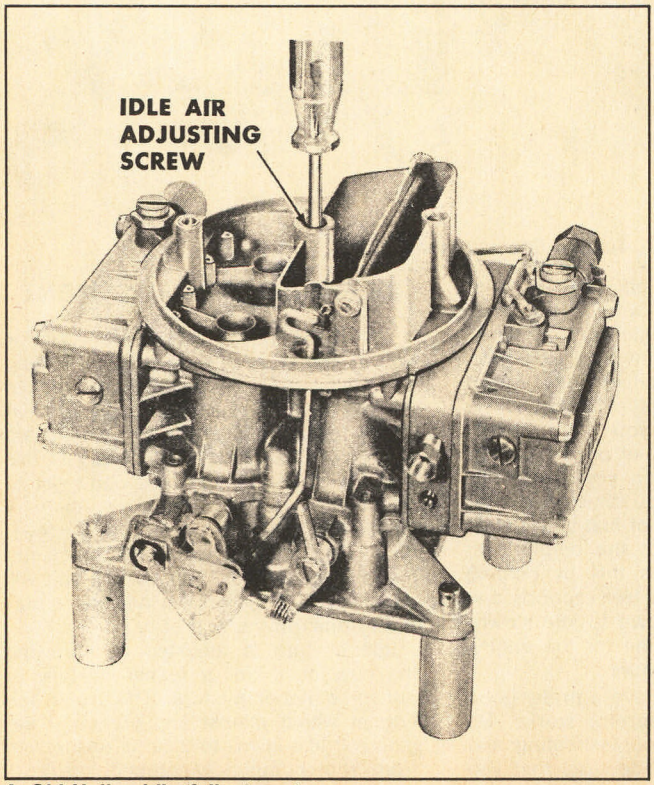
1. Business End of Holley 4500



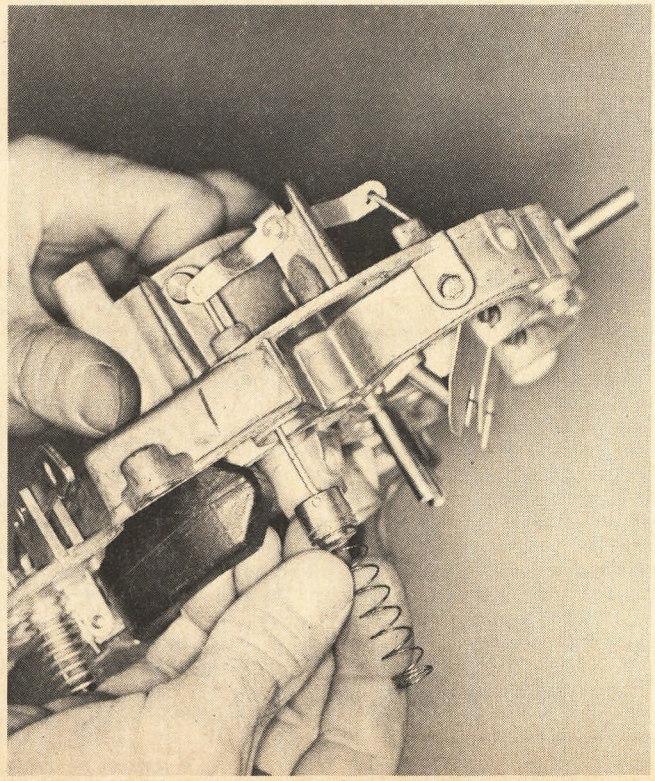
2. Holley Secondary Metering Plate



3. Rochester 4MV Idle Screw



4. Old Holley Idle Adjustment



5. Air Valve Piston

those engines with air injection pumps (smog pumps). These engines must have a richer exhaust to burn up the hydrocarbons, so the mixture needles are usually adjusted ¼-turn out (richer) from the lean roll point.

AIR/FUEL RATIO

Air/fuel ratio is a fancy term that you won't hear much. What you will hear is talk about a carburetor running rich or running lean. Running rich means that the engine is getting too much fuel; running lean means just the opposite. Sometimes running rich provides an obvious symptom such as black smoke coming out of the tailpipe, but most of the time if the mixture is off it will show up either as poor gas mileage or a lack of power.

If you want power, it takes gasoline to produce it, so you can usually assume that the engine is running too lean if it doesn't seem to have much push. If the gas mileage is so poor that you can't even make a short trip without stopping at three gas stations, then you can be pretty sure that the mixture is too rich.

Carburetor men measure the air/fuel ratio with an exhaust gas analyzer. The analyzer takes a sample of the gas from the tailpipe, and a meter gives the ratio of air to fuel by weight. An engine will run from about 11-to-1 up through 15-to-1. Carburetor men have always felt that mixtures leaner than 16-to-1 wouldn't even run an engine, but with refinements in emission controls, the carburetor makers are now talking about mixtures in the area of 20-to-1. The ordinary exhaust gas analyzer is useless with such lean mixtures. The needle will reverse, going off scale to the rich side. So most shops are now getting hydrocarbon meters, which are expensive.

Some carburetor men don't use an exhaust gas analyzer. But the ones who do have found that the small amount of time it takes to hook the analyzer up will save them a lot of trouble in the long run because it gives them an immediate check on how well the carburetor is running, both before and after they have worked on it.

It is not necessary for you to go out and buy an exhaust gas analyzer. A good one is expensive, a bad one is worse than none at all. And there are some bad ones on the market. The point is that when working on a carburetor you are mainly concerned with mixture control. Power, performance, and smoothness are all dependent upon having the right amount of gasoline in the air to match the needs of the engine.

Of course the greatest enemy of mixture control is dirt. If the idle mixture needles will not adjust or you keep having problems with rough idle and stalling, just look at the outside of the carburetor. If it's all encrusted with fuel residue and dirt, you can be pretty sure it's almost as dirty on the inside. So the first thing you have to do is get it clean.

CARBURETOR CLEANING

Removing a carburetor is more or less an obvious procedure. It is held on at the base by studs and nuts. Remove the nuts, the throttle linkage, the hot air tube to the choke housing (if there is one), and any wires to such things as the transmission kick-down switches or air-conditioning idle speed-up switches. Remove the carburetor and take it to the bench for disassembly procedure.

Exploded views of carburetors usually show the parts as if they were disinte-

1. Secondary linkage on Holley 4500 is concealed in a cavity between the throats. Linkage is rugged.

2. On the Holley 4160, the secondary metering block is a thin plate with no replaceable jets.

3. Secondary linkage on Rochester 4-bbl. is a rod that can be adjusted by bending. Screw (arrow) is for curb idle adjustment.

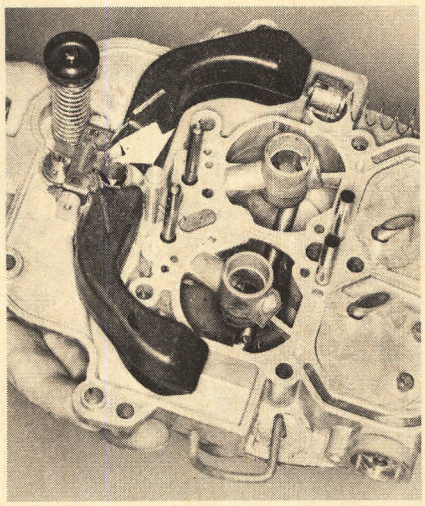
4. The idle air screw is a means of supplying air to run the engine when the design of the carb allows the throttle plates to close completely at idle. You'll never find this one if you don't know it's there, because the air cleaner stud screws in on top of it. A disadvantage is that idle adjustments must be made with air cleaner off.

5. Air valve piston on the 4300 has small spring underneath that returns the air valve to the closed position.

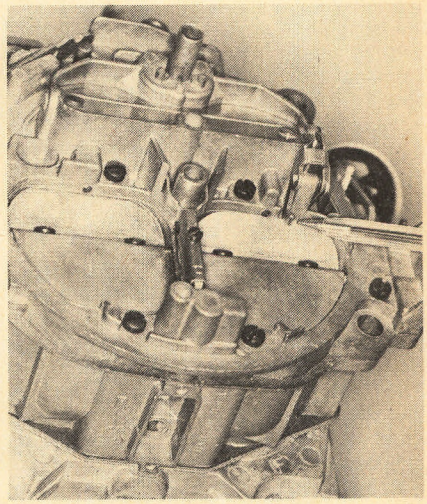
6. Power piston stem on 4300 is just visible between halves of float. It opens the power valve, which is in the bottom of the bowl.

7. When the Rochester 4-bbl. choke is on, this little tab prevents the secondary air valve from opening. That's so you can't get on it when the engine is cold.

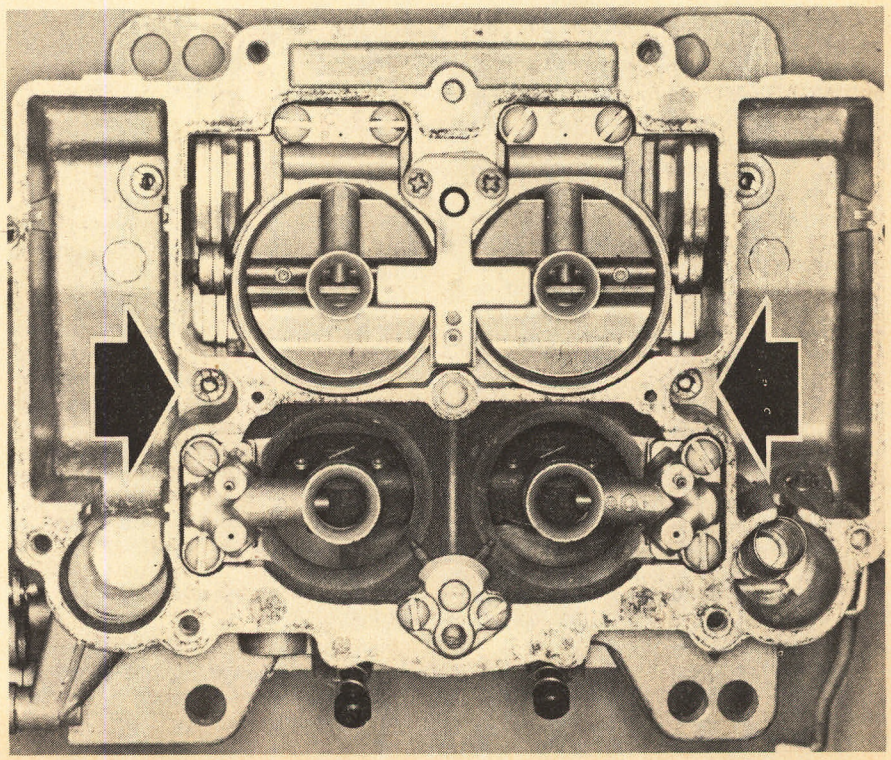
8. Carter AFB primary main jets are in the little niches (arrows). Secondary main jets are in the end of the bowl.



6. Power Piston



7. Rochester Choke Lock-Out Tang



8. AFB Main Jets

grated by a bomb. Never under any circumstances take a carburetor apart this far for cleaning. A good rule to follow is that anything with a gasket should be removed so that the gasket can be renewed. Also any jet that is screwed in should be removed so that the cleaning fluid can get up into the passages behind the jet. Choke vacuum pistons should be removed if they are of the type that is built into the carburetor.

Never under any circumstances should throttle shafts or choke shafts be removed for ordinary cleaning. If you do you'll just be making a lot of extra work and you won't be accomplishing anything because the cleaning solution easily finds its way alongside the throttle and choke shafts without their being removed. If power valves are the screw-in type, they can be removed. If they are pressed or staked in, they should be left alone.

After the carburetor is disassembled, the large parts should be put in a basket and the small parts in a closed screened container which will allow cleaning solution to enter but keep the small parts from being lost. A good holder for small parts is a tea ball, ordinarily used for making tea, available at any store with a housewares counter.

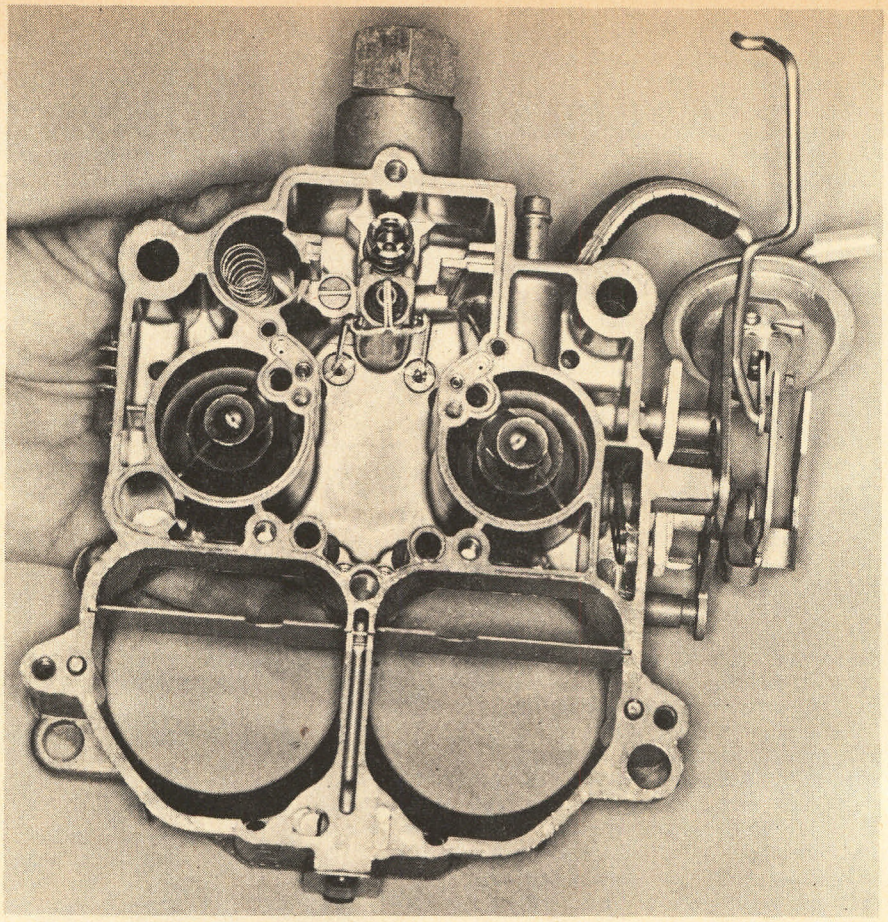
The basket for the large parts comes with either a 3- or 5-gal. bucket of commercial carburetor cleaner. However, if you are only doing one or two carburetors a year, you can buy the carburetor cleaner in pint cans to do the cleaning. Use a coat hanger to fish the parts out. The cleaner is a very powerful chemical—you should never put your fingers in it and be very careful not to splash it in your eyes.

Some cleaners will clean a carburetor in 20 mins. Others won't do a very good job. You will have to find out by experimenting with what is available in your area. Any cleaner will ruin rubber or neoprene parts, so if there are any parts like this in your carburetor be absolutely certain they are removed before the carburetor is dunked.

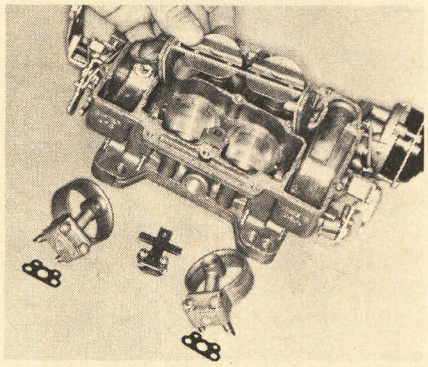
After the carburetor has remained in the cleaning solution long enough, the whole basket should be removed and allowed to drain. Then all the parts can be submerged in cleaning solvent or kerosene. If the carburetor cleaner did its job right, the solvent is only to wash out the cleaner, but in some cases you may have to use a brush with the solvent in order to loosen and remove some of the more stubborn deposits.

Swish the carburetor around in the solvent so that all the cleaner is washed out of it. Then remove the carburetor piece by piece and blow all the passages with compressed air. If you don't have an air compressor then blow the passages out with a tire pump. At least be sure that you blow the carburetor with something so that you will remove any remaining pieces of dirt.

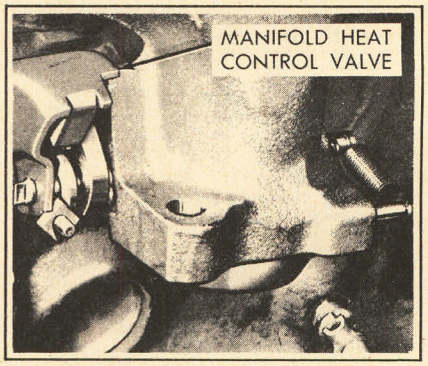
After the carburetor is clean, it's simply a matter of reassembling it with new gaskets and new parts where necessary and checking the various adjustments on the carburetor. You should never put a



1. Inside The Float Bowl



2. AFB Air Valve



3. Heat Riser Valve

carburetor back together with the old gaskets unless it's an emergency. At least buy a gasket set or have one on hand before you start the job.

The next step up from a gasket set is a zip kit or pep kit. This includes gaskets plus a few of the parts that wear out, such as needle and seat and accelerating pump. If the carburetor is really in bad shape, then you will need an overhaul kit which includes just about every part on the carburetor that could wear out except the shafts. If even an overhaul kit won't restore the carb, then your only recourse is to buy the parts that you need. However, it is usually cheaper to buy a new carburetor than it is to go that far.

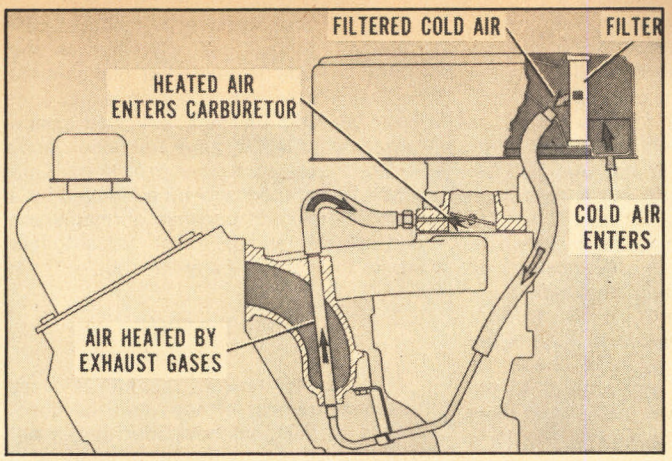
While assembling the carburetor you will set the float leve, but that is ordinarily the only internal adjustment. After the carburetor is assembled there are all kinds of external adjustments that make it operate correctly.

When you buy a repair kit for your carburetor there will usually be a sheet included that will show all the adjustments and specifications. If not, there are auto repair manuals available at bookstores that will give you this information. Also the factory shop manual put out by the manufacturer of your car has all this data.

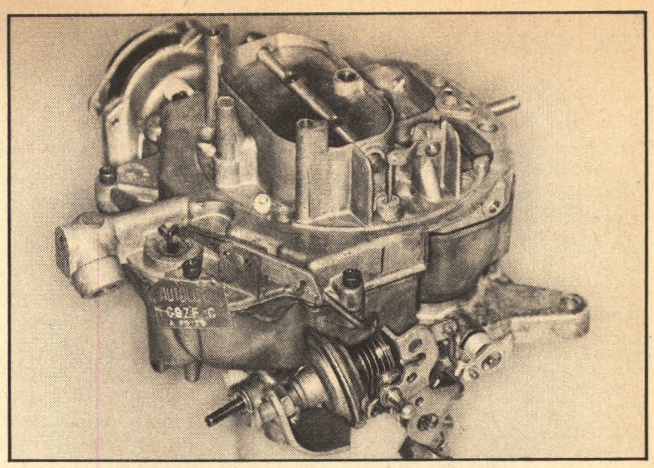
If after you get the carburetor back on your car, it still doesn't run right, you may have to change the jets. This is usually not necessary. In fact, in some cases it will increase exhaust emissions and is therefore illegal. But changing jets is a procedure that you must know to make a carburetor work correctly.

IDLE JET

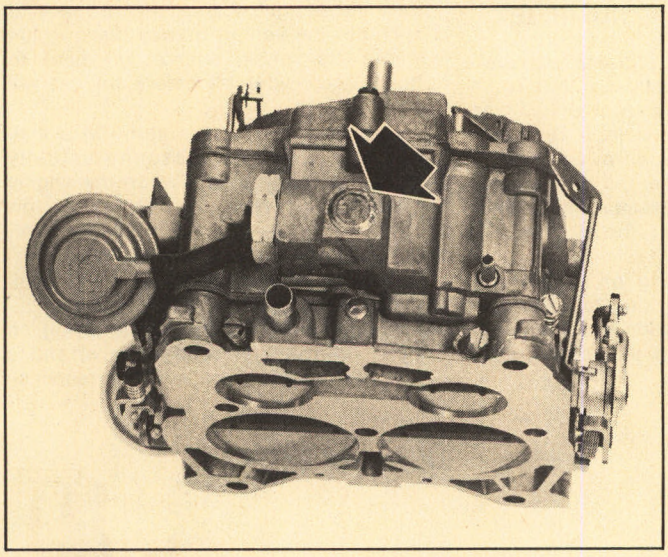
After the fuel enters the idle jet it picks up air as it moves through the idle passage in the carburetor. When it reaches the idle port below the throttle



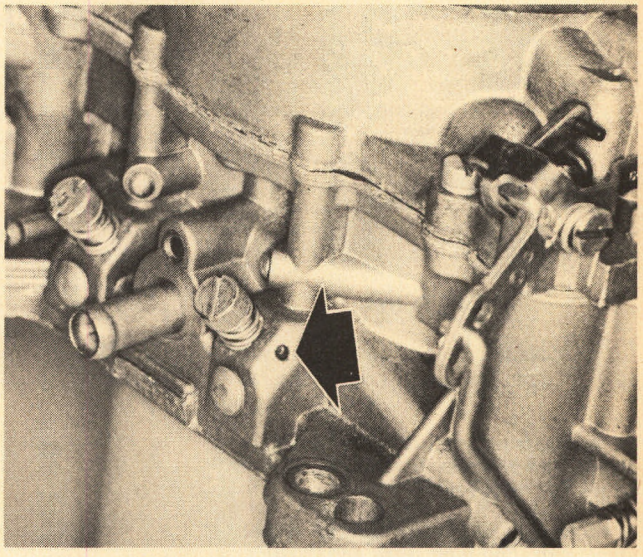
4. Anti-Icing System



5. Anti-Stall Dashpot



6. Rochester 4MV



7. Mixture Screw Retaining Pin

1. Lift the Rochester 4-bbl. bowl cover off and this is the sight that will greet you. We have also removed the float, needle and baffle.

2. Remove the secondary clusters on an AFB and then the secondary air valve will come out.

3. This may not look like part of carburetion, but it is. If the heat control valve is stuck shut, forcing too much heat up under the carburetor, it can cause uneven running.

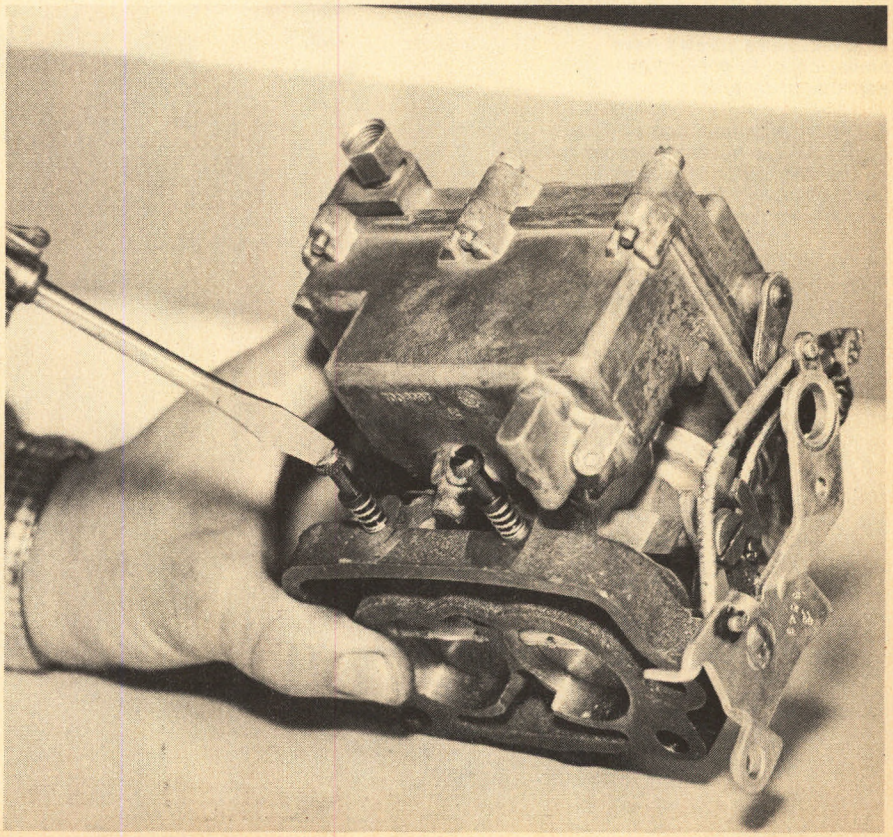
4. Some cars have trouble with throttle plate icing, which causes the engine to die or results in extremely rough running. This system on a Chrysler Slant-6 channels heated air to underside of throttle plate and prevents icing.

5. Anti-stall dashpot on autolite 4300 is not connected to engine vacuum. It works on a bleed-down principle.

6. Ever hear of a Chevy burning up? Sometimes this plug falls out, which gives the engine a gasoline bath.

7. To prevent over-rich adjustments, the idle needles on some carbs are limited with a pin in the body of the carburetor.

8. Go easy when using a screwdriver on idle mixture needles. They can easily be ruined if they are screwed in tight against the throttle bore.



8. Adjusting Mixture Screws

plate, it is in reality a mixture of fuel and air, and it is the amount of this mixture that you control with the idle mixture screw. However, the idle mixture screw does not control the fuel that comes from the idle transfer port. That fuel mixture is controlled by the size of the idle jet and the idle air bleeds.

If the idle jets are screwed in it's a simple matter to change them. However, if they are pressed into a metering cluster, the only way to change idle jet size is by drilling or buying a different cluster, if one is available—and it usually isn't.

MAIN JET

Main jets are usually screwed in and easily changed. However, main jets for the secondary side of a 4-bbl. carburetor may be just orifices which are not removable. When removing main jets be sure to use a screwdriver that fits the slot in the jet. If you don't, it's very easy for the screwdriver to slip part way out of the jet and chew up the soft brass. On a carburetor that uses metering rods, the usual procedure is to change the rods.

POWER JET

If you want a richer mixture at wide open throttle, but wish to retain the mixture you already have at cruising speed, then the power jet is the one to change. A lot of ingenuity has been used in the design and placement of power jets and sometimes you have to use almost an equal amount of ingenuity to find them. Some of them cannot be changed because they are nothing but a restriction in a passageway. Others can be changed or drilled in order to enrich or lean the wide-open throttle mixture. In most carburetion tuning on stock automobiles, the power jet is seldom changed. The best reason for this is because the only way you can check the mixture to find what you have is to put the engine on a dynamometer—and there aren't many dynamometers that are readily available.

ACCELERATING PUMP JET

Accelerating pump jets can also be a restriction in a passageway that is impossible to change or even drill. Sometimes the restriction is in a removable pump nozzle that is screwed into the carburetor throat. If so, the nozzle sometimes has a number stamped on it which indicates the size of the accelerating pump restriction.

Drilling or changing of accelerating pump jets is usually done to eliminate a flat spot on acceleration that cannot be cured by lengthening the stroke of the pump.

It is possible to have 99 identical carburetors that will run well, but on the 100th one the accelerating pump might be just a trifle lean, causing a flat spot when you step on the gas. In that case a larger pump jet or pump restriction does wonders to cure the problem. This procedure should only be attempted by a carburetor expert because ordinarily you can set the pump linkage for a longer stroke to overcome any flat spot.

FLOAT LEVEL

It's easy to think of the fuel level as the measurement of how high the gasoline is in the float bowl, but this is not the part that's important. The critical point is the main nozzle and whether the gasoline is right at the tip of it ready to spill into the venturi or way down inside where the venturi suction will have to build up considerably before any gas will come out.

Fuel level can be so high with a maladjusted float that gasoline actually drips out of the nozzle when the engine is shut off, or fuel level can be so low that venturi suction cannot pull the gasoline out of the nozzle and the engine will gasp and wheeze instead of cruising along.

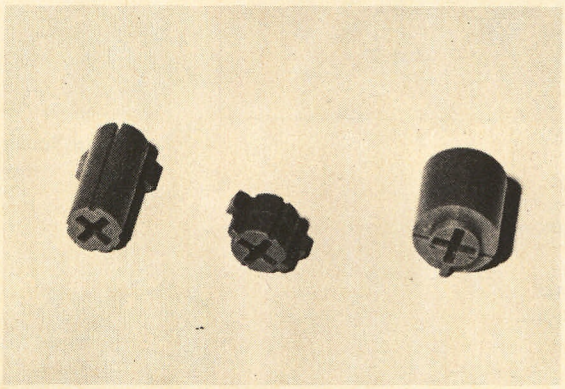
A high fuel level can cause dying on turns or dying on sudden stops, and a low fuel level can cause poor response

1. Replacement mixture screw caps come in all sizes to fit various carbs. These are Rochester.

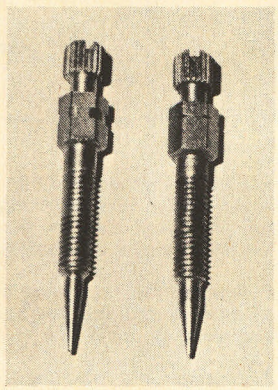
2. Mixture needle on left has 15 degree taper, providing finer (less sensitive) adjustment on '72 Buick 2-bbl. Needle at right is old style, with sharp taper.

3. Idle mixture screws have limiter caps, to prevent over-rich adjustment by tuners.

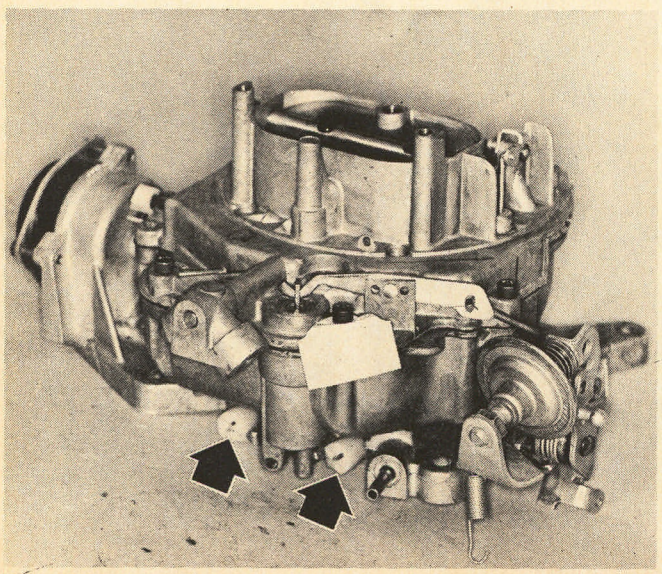
4. Electrical connection on this Carter AVS is for the solenoid retard on the distributor. It retards the spark at closed throttle. Idle speed screw is above terminal



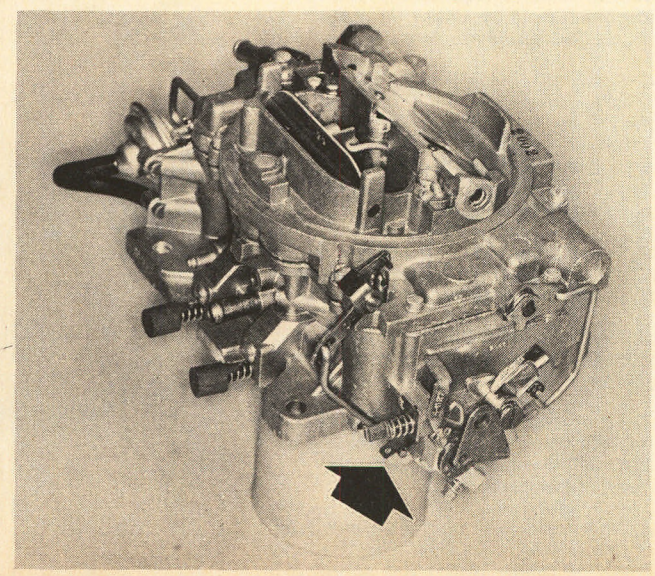
1. Mixture Screw Limiter Caps



2. Idle Needle Taper



3. Idle Mixture Screw Caps



4. AVS 4-Barrel

when the main metering system attempts to take over from the idle system. With experience you will be able to recognize high fuel level or low fuel level because of the way the engine acts.

Suppose you have a car that runs very good at high speed but extremely rich at idle so that the engine rolls. You adjust the idle mixture screws but it doesn't help, so the logical thing to suspect is the fuel level. There are many problems that are obvious if you just give them a little thought and analysis.

CRANKCASE VENTILATION VALVES

The so-called smog valve can cause mixture problems too because it is allowing crankcase vapors to enter the engine. These crankcase vapors are mostly unburned gasoline or just air, on an engine in good shape. On an engine in bad shape there is a lot of oil smoke mixed in with them.

The only thing you can do with smog valves is to make sure that the hoses connecting them do not have any leaks and that the valve itself is clean. If the valve is an orifice type, a visual inspection is good enough. If the valve is a plunger type you should use both a visual inspection and shake the valve to be sure that the plunger is completely free inside.

Smog valves can be cleaned in carburetor cleaner, although many car makers recommend replacement instead of cleaning. Since the smog valve is allowing unburned gasoline or air to enter the engine, if you pinch the hose or if you put your finger over the end of the valve, the engine will actually idle slower because you are taking some of the air and gas away from the idle mixture. If the engine does not idle slower then you can be pretty sure that the valve is plugged or restricted.

AIR CLEANERS

Nothing will make an engine run rich quicker than a clogged or restricted air cleaner. If the element in your cleaner is made of foam or steel mesh, it should be cleaned in solvent or kerosene, shaken or squeezed dry and lightly re-oiled. Foam-type elements must be handled with care because they are fragile and frequently split at the seam where they are glued. If you have this trouble, instead of repairing them or getting another foam element, there are paper elements available that will take the place of the foam.

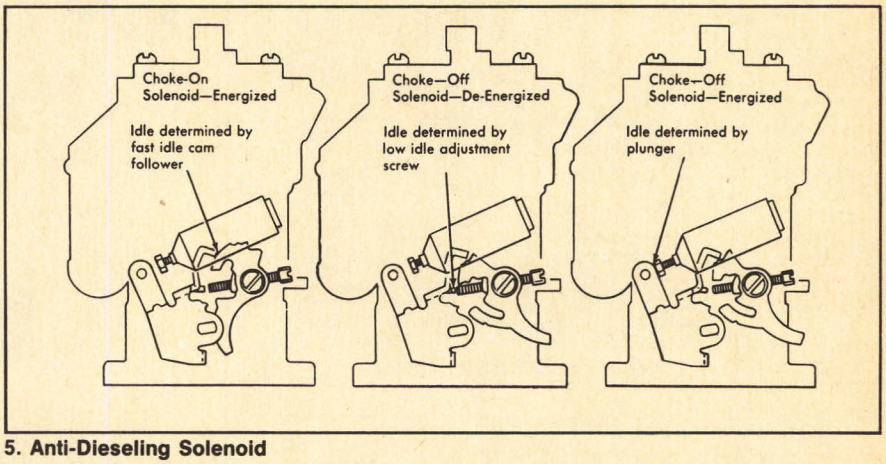
If you have a paper element, you can gently tap it or blow it to clean it. But the best idea is to throw it away and put on a new one. The best test ever devised for a paper element is to hold it over a bare light bulb. A new element will look bright and clean while a dirty one is obviously plugged up.

When cleaning air cleaners of any kind, the housing should be cleaned with solvent, but do not submerge it in a solvent tank. There are inner chambers that can become full of solvent and it's impossible to pour it out. Also be very careful not to cut your fingers when you are wiping out the inside of an air cleaner. The cleaner is made of sheetmetal,

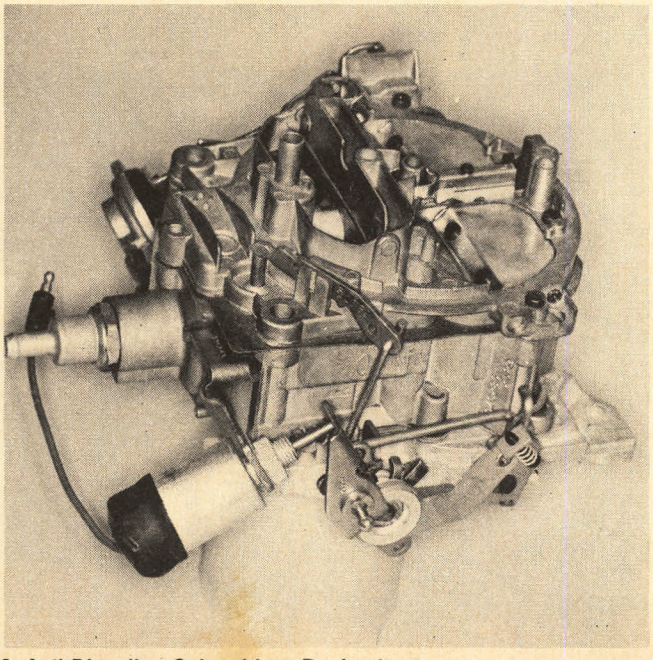
5. Many cars use anti-dieseling solenoids. Normal curb idle is controlled by the adjustment screw in the solenoid itself. If the solenoid has a wire only going to it, then it is a true anti-dieseling solenoid. But if there is also a vacuum line to the solenoid, then it is a CEC valve, which is never used to set curb idle.

6. Rochester 4-bbl. with anti-dieseling solenoid. Curb idle is set with the solenoid adjustment.

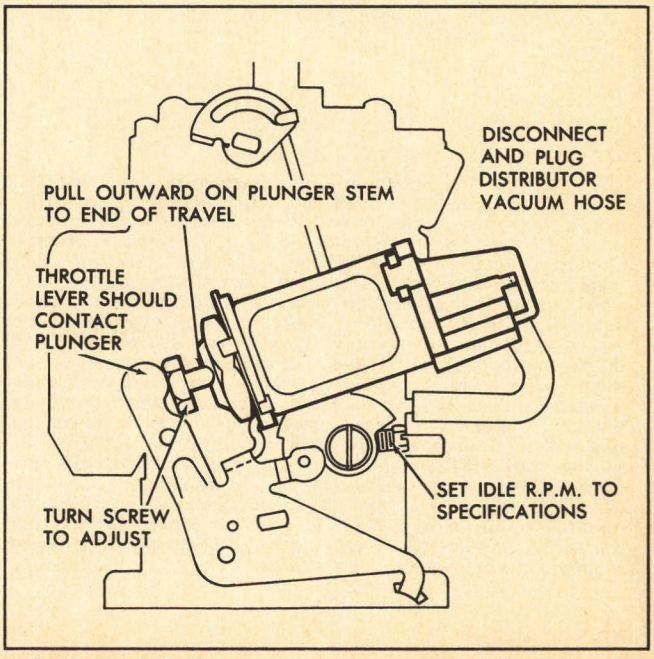
7. The Combination Emission Control Valve (CEC) is used mostly on Chevy cars, but also appears on some other GM makes. Curb idle is set with the normal throttle cracking screw, not the CEC plunger screw. There is a specification in rpm for the plunger screw, but setting it is not necessary unless you disturb the original setting. CEC valve rpm setting varies as much as 300 rpm above normal curb idle. If you set curb idle with the CEC valve plunger by mistake, engine braking on deceleration will be greatly reduced, which can be dangerous.



5. Anti-Dieseling Solenoid



6. Anti-Dieseling Solenoid on Rochester



7. Chevrolet CEC Valve

and there are sharp edges that can really cut.

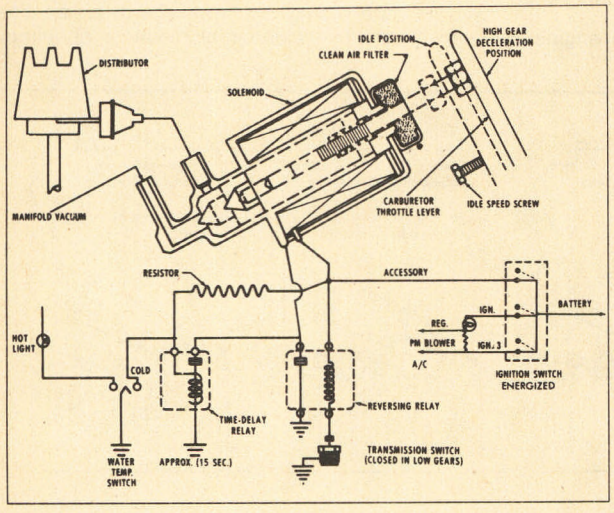
FUEL DELIVERY TESTING

If possible, you should not think in terms of testing a fuel pump no matter how much you read elsewhere about testing procedures. If you will think only of testing fuel delivery at the carburetor, you will be a long way toward solving whatever the problem is.

To test fuel delivery take the line loose at the carburetor, slip a tight fitting rubber hose over this line and let the hose dangle over the fender into a bucket. Then start the engine and let it idle just on the fuel that is in the carburetor bowl. You will get a series of squirts into the bucket as the fuel pump operates. An experienced mechanic can just look at the size and length of the squirts and tell if the pump is in good condition or not, but you should actually measure the amount of fuel that you get in half a minute. Ordinarily this would be about a pint if the pump is in good condition.

We had a peculiar experience with a new fuel pump that illustrates the fuel delivery problem. The car would starve for fuel on full throttle acceleration, especially on long, uphill, freeway on-ramps. The original fuel pump on the car was a Carter, but instead of buying another Carter we bought a brand new pump made by another company. With the new pump installed, the fuel starvation was still there, even though the new pump put out a pint of fuel in less than 30 secs. Everybody we talked to said there couldn't be anything wrong with a fuel pump that would put out like that. But we stuck to our guns, hunted up a Carter dealer, and bought an original equipment Carter pump. After installing it, the car ran beautifully, without a trace of fuel starvation. Then, to satisfy our curiosity, we tested the new Carter pump, and found out it would put out a pint in 18 secs. That's a heck of a lot of fuel, but evidently the engine needed it, and Carter's original equipment pump was designed to put it out. The other manufacturer's new pump was evidently a universal design that would fit anything, but it wasn't good enough for our engine.

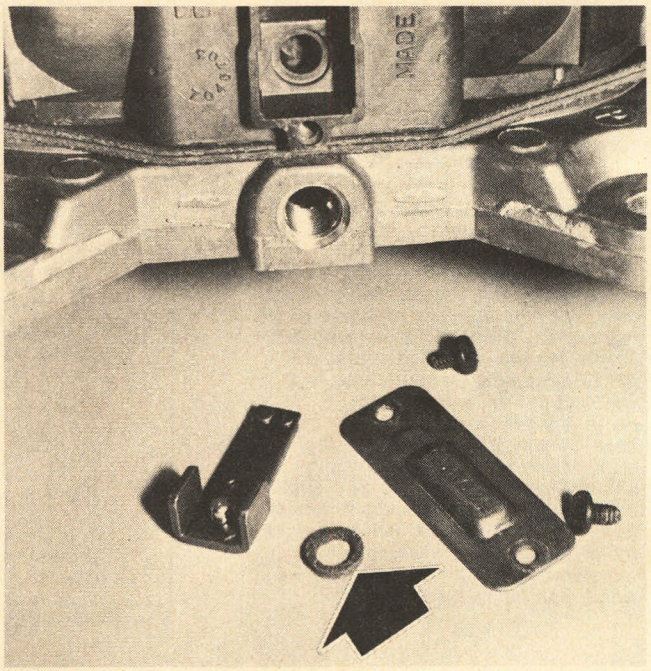
If you have good fuel delivery then you are pretty sure there is nothing wrong from that point all the way back to the tank, but you still haven't tested the passageway from the carburetor inlet fitting into the float bowl. This passageway frequently contains a bronze filter. The easiest way to test it is to dip it into a bucket of gas and see if it will hold the gasoline. If it does, throw it away and put on a new one, because that means that the pores in the bronze are filled with dirt.



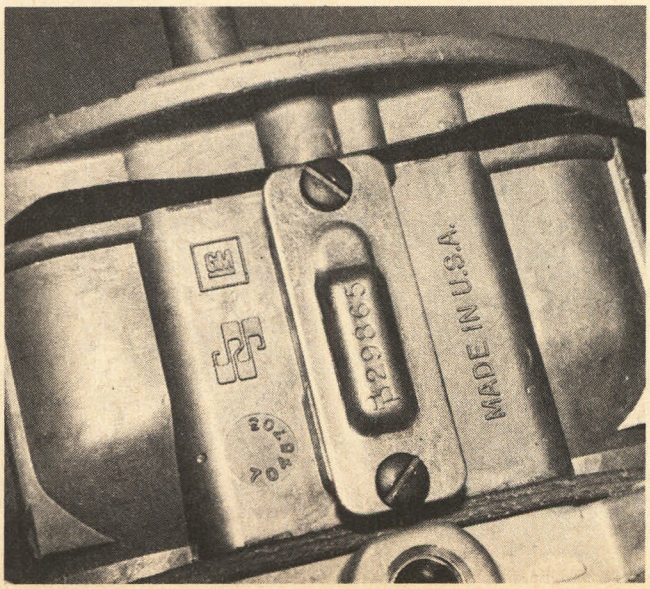
Transmission	GEAR						
	Park	Neutral	Reverse	1st.	2nd.	3rd.	4th.
3 Speed	-	-	-	-	-	Vac.	-
4 Speed	-	-	-	-	-	Vac.	Vac.
Torque Drive	-	-	-	-	Vac.	-	-
Powerglide	-	-	-	-	Vac.	-	-
Turbo Hydra-Matic 350	-	-	Vac.	-	-	Vac.	-
Turbo Hydra-Matic 400	-	-	Vac.	-	-	Vac.	-

CEC Valve Adjustment

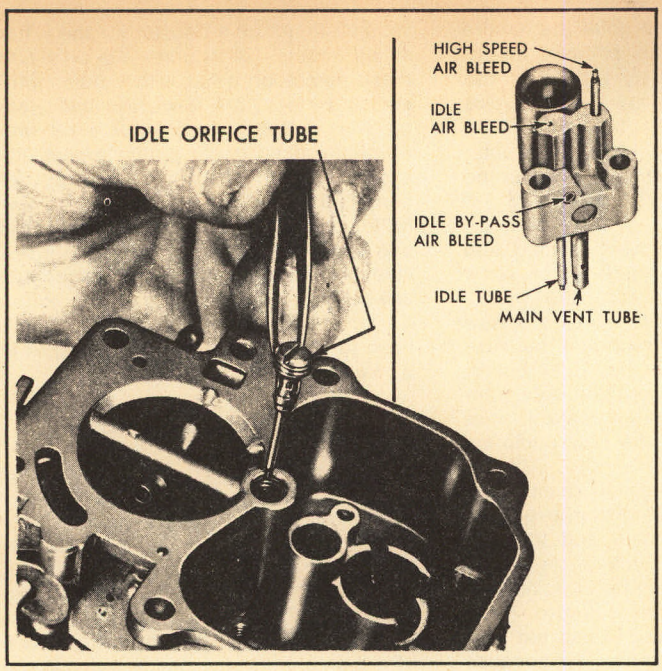
CEC (Combustion Emission Control) valve is a complicated arrangement because it does so many different things. Using a combination of electricity and engine vacuum, the valve controls spark advance and throttle opening. The valve is normally closed, which shuts off vacuum to the distributor and eliminates all spark advance. When the transmission is in a position labeled "Vac" on the chart, the transmission switch opens, which operates the reversing relay to energize the valve. This opens the vacuum line to the distributor, giving normal vacuum advance, and also extends the plunger to the high gear deceleration position which gives a larger throttle opening on deceleration for fewer emissions. The water temp switch is in the circuit so that the CEC valve is energized below 82°. The time delay relay energizes the valve for 15 seconds after the ignition switch is turned on, to improve cold running. But we're not through yet. An additional solid state device turns on the air conditioner for three seconds after the ignition switch is turned off, to stop the engine and prevent dieseling. This is '71 model. The '72's have slightly different hookup, to keep you on your toes.



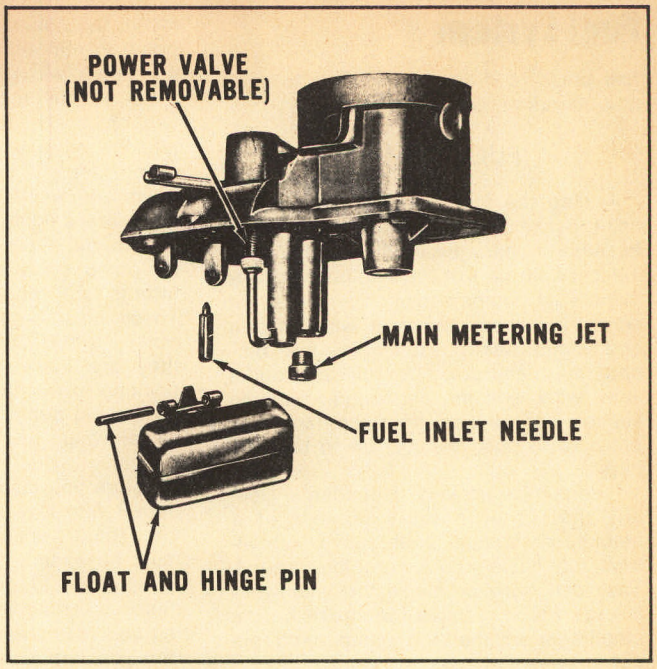
1. Hot Idle Compensator



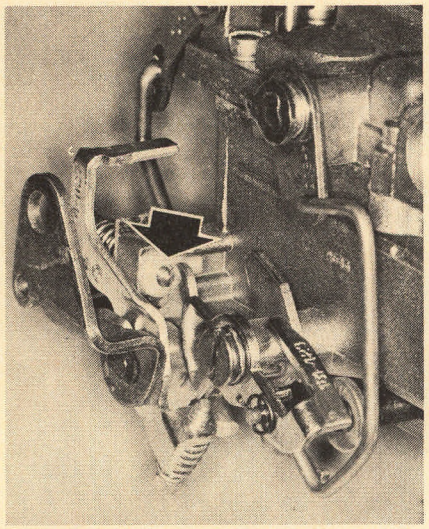
2. Compensator Cover



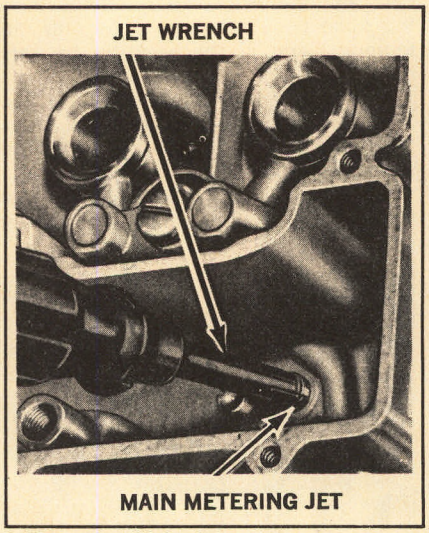
3. Idle Jets



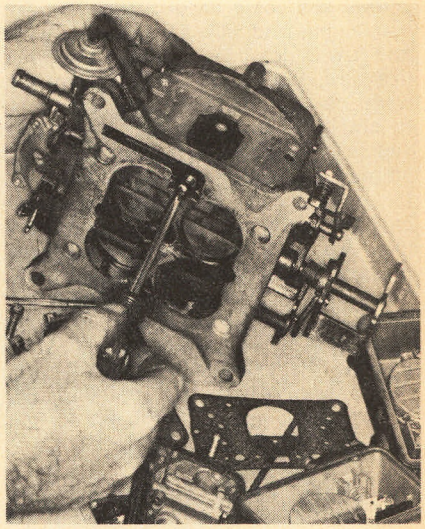
4. Main Jet Location



5. Chrysler Retard Solenoid Contact



6. Removing Main Jet



7. Carburetor Cleaning

1. Remove the cover on this carb and there is a hot idle compensator. Note gasket, important to prevent leaks.

2. Under this cover on a Rochester may be a hot idle compensator or nothing at all.

3. Idle tube is another name for the idle jet. The calibrated restriction is at the lower end of the tube where it appears pinched together.

4. Autolite 1101 upper body. You might also hear this called the air horn or the bowl cover.

5. Terminal on Chrysler product Carter retards spark at idle. If contact is not made, idle will be too fast, since spark will remain advanced.

6. Main jet on this Ford-Autolite 2100 carb is on the floor of the bowl.

7. Carburetors should be disassembled thoroughly for cleaning, but only by removing screws or clips. It isn't necessary to remove any rivets or lead plugs that are pressed in.

If you don't have good fuel delivery at the carburetor, then start checking each component all the way back to the tank. This may include a fuel filter mounted on the engine, a fuel filter on the tank side of the fuel pump, a filter in the line between the pump and the tank and maybe even a filter on the pickup tube inside the tank.

Any of those filters could be restricted because of dirt or water. If they are, change the element or if it's a throwaway filter, change the whole filter. If you find nothing wrong with the filter, then it's time to start checking for a kinked line. This can happen because somebody jacked up the car where a line runs outside the frame. Or it could have been caused by a mild collision that kinked a hose. Take nothing for granted when you work on a fuel system. Just because a rubber hose looks good on the outside doesn't mean that the inside isn't all swelled up so that it won't pass any fuel.

A complete fuel delivery test also involves testing the pressure at the carburetor. Do this by inserting a T in the line and checking fuel pressure with the engine idling, or pressure can be checked statically. Disconnect the line from the carburetor and hook it directly to a pressure gauge, then idle the engine and check the pressure.

Correct pressure can be anywhere from 1½ lbs. to 6 lbs. at idle. On older cars, part of the pressure test was to shut the engine off and see if the pressure would hold, or at least only fall very slowly. This test is not valid on late-model cars, because they have a bleed-back feature in the pumps or in the fuel filter that allows fuel pressure to drop to zero whenever the engine is shut off.

Did you ever park a car in the hot sun on a day when the mercury was up at the top of the thermometer? Fuel pressure can go high enough to override the float and fill the bowl to over-flowing so that fuel runs into the engine. Then when you come back to your car you have several minutes cranking ahead of you before you finally get your flooded engine cleaned out. The bleed-back feature on late-model cars eliminates this problem. When the engine is shut off,

fuel pressure drops immediately to zero and, therefore, prevents flooding.

FUEL PUMPS

Finding the fuel pump is not too difficult, but removing it can really be a job because in many cases it is in the most inaccessible part of the engine compartment. Fuel pumps usually operate off an eccentric on the camshaft with an arm and some linkage to move the diaphragm up and down. An inlet and outlet valve work with the diaphragm, creating suction on the line from the tank and pressure to push the fuel up to the carburetor.

Fuel pumps are very dependable. Usually their malfunctions consist of a cracked or broken diaphragm which allows fuel to leak out onto the ground. They can have problems too with worn linkage which reduces the stroke on the diaphragm so that the pump can't put out the way it should.

Older pumps were put together with screws and could be disassembled. The diaphragms and valves were replaceable and it was possible to rebuild the pump like new. But rebuilt exchange pumps were inexpensive so it really didn't pay to put in a new diaphragm and valves yourself. The result was that most parts stores quit handling replacement parts for pumps and only sold rebuilt exchanges or new pumps. In a few years there won't be any more rebuilt pumps, because the late-model cars all use a pump with a crimped edge instead of screws. Those pumps cannot be taken apart. They must be thrown away when they go bad. The most practical thing to do in any case when a fuel pump is bad is to throw it away and put on either a good rebuilt or a new one.

FUEL PUMP REMOVAL

To remove the pump, simply disconnect the lines, take off the two capscrews holding the pump on the engine block and remove the pump. There are usually two fittings where a line enters a pump. If you put a wrench on the outer fitting and start turning it to take the line loose, the chances are good that you're going to ruin something, because the inner fitting will turn also. Whenever you take a line loose, always use two wrenches, one to hold the inner fitting and the other wrench to turn the outer fitting. Ideally you should use tubing wrenches to keep from rounding off those brass fittings.

After the lines are disconnected and the pump is removed, there will be some fittings still screwed into the pump. These must be transferred to the new pump. If they are directional be sure they are installed in the new pump, pointing in the same direction they were on the old pump. That will make it a lot easier when you put the new pump on the car.

Before you install the new pump compare it with the old pump from every angle. The mounting flange and the arm must be exactly the same configuration as on the old pump. There is nothing more sickening than the sound of hearing your camshaft break in half the second you turn your engine over because the pump arm was jammed between the cam and the block. Many pumps have the same body and flange, the only difference being in the arm. So be very careful.

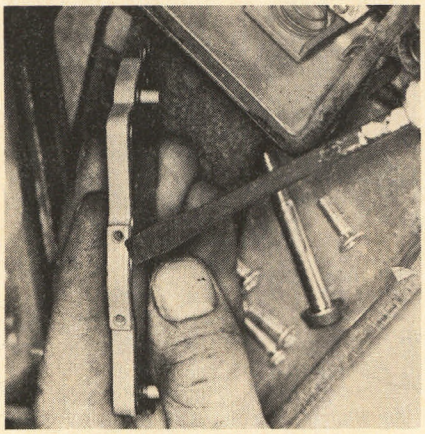
If there is a pushrod that operates the pump, be sure the pushrod is not worn. If in doubt, replace it. A worn pushrod will not give full stroke.

Some pumps are dual, with one half pumping fuel and the other half creating vacuum to act as a booster for the windshield wipers. Of course you only find those pumps on a car with vacuum wipers, and most cars nowadays use electric wipers. But if you do have a car with a double pump that's giving trouble, it's a good idea to check the camshaft eccentric. Those double pumps put an awful lot of pressure on the cam eccentric and can wear it down to where it's just a little bit of a nub. In case the eccentric is worn, the easiest way to fix it is to put on an electric pump. Otherwise, you'll have to tear the engine down and put in a new cam.

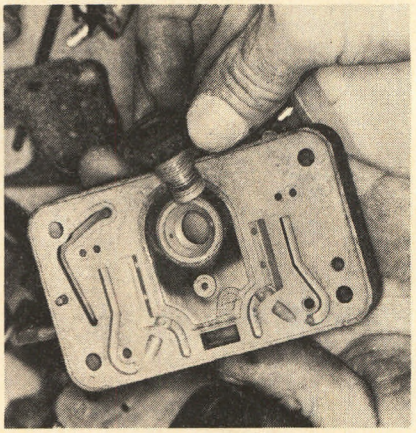
ELECTRIC FUEL PUMP

Foreign cars have used electric fuel pumps for years but they have never caught on for domestic vehicles. Probably the reason is that electric fuel pumps can cause operating difficulties if the driver is not aware he has an electric pump. The electric pump is operating any time the ignition is on. If a piece of dirt gets under the needle valve in the carburetor and the engine floods and dies, the driver may leave the ignition switch on. Of course the electric pump is still operating, so it'll pump the complete contents of the gas tank into the carburetor and out over the top of the engine and onto the ground, which is a bit inconvenient.

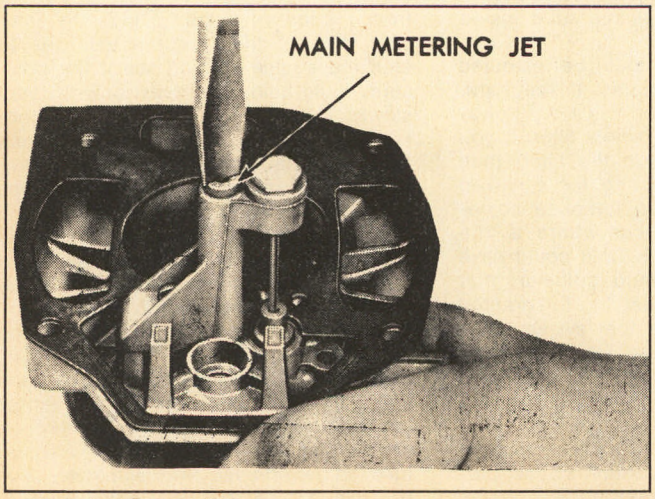
There are ways around that by installing an oil pressure switch so that the electric pump will not operate until the



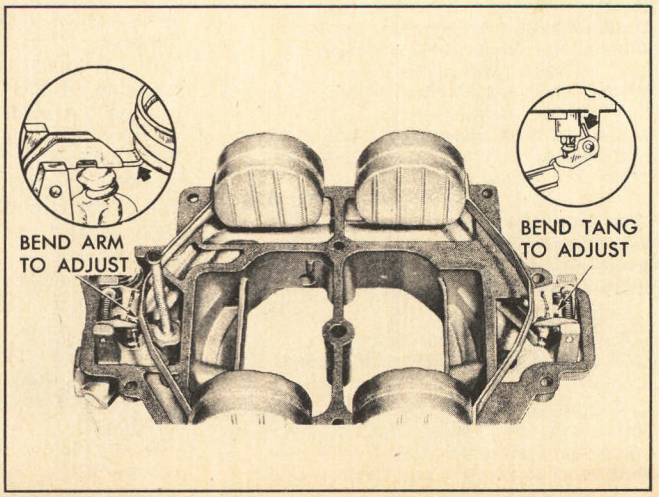
1. Holley Secondary Main Jet



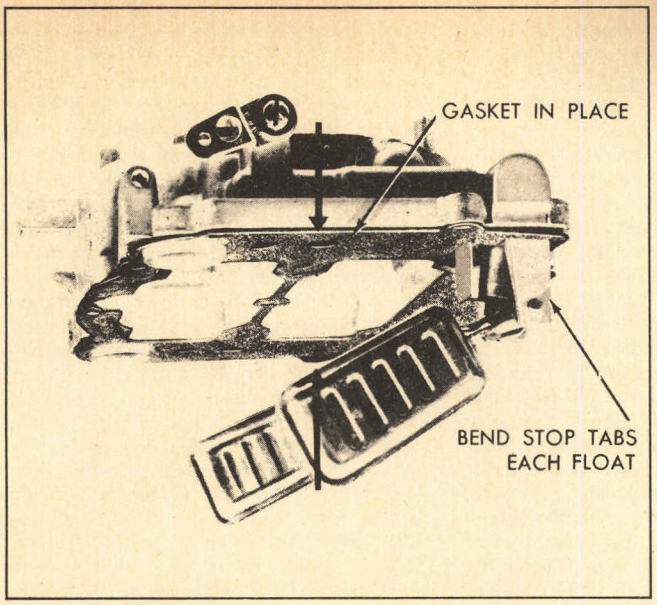
2. Economizer Valve



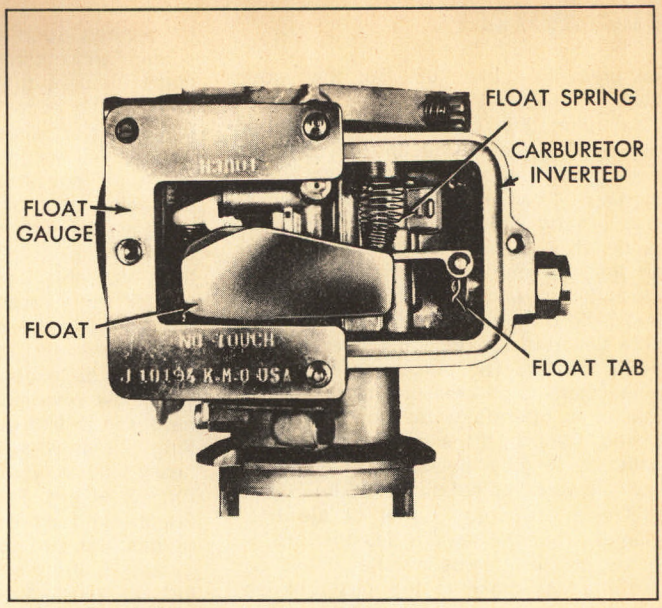
3. Main And Power Jets



4. Adjusting Float Level



5. Checking Float Drop



6. Float Level Gauge

1. With the Holley secondary metering body removed, you can see the little holes on the bottom of it that are the secondary main jets. They are not removable.

2. Holley calls this little screw-in part an economizer valve, but it's really a power valve, or power jet.

3. Rochester model B 1-bbl. has power jet under cap next to main metering jet. Check power jet to be sure spring is not broken. Broken spring makes engine run rich all the time.

4. Float level adjustment is usually achieved through bending a float arm or tang. This 4-bbl. carburetor features both methods. On the left is the bending point for setting the level, and on the right is the adjustment for float drop.

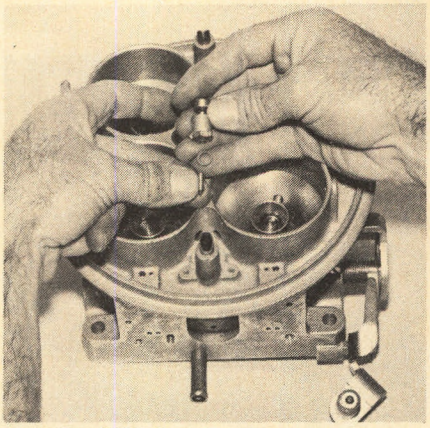
5. Float drop is not as precise a measurement as float level. In many cases there is no precise point on the float from which float drop is measured.

6. This single-barrel Holley carburetor is representative of many 2- and 4-bbl. units in that float adjustment is done by bending the float tab rather than the float arm.

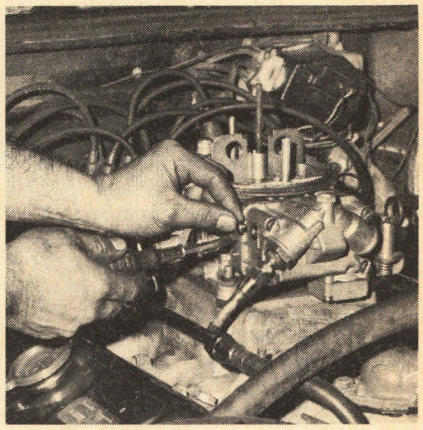
7. On Holley 4500, accelerating pump discharge check is under the pump nozzle on top of the carb. Holes in nozzle meter the fuel.

8. Here, when the float is adjusted correctly, gasoline should just wet the bottom of the threads in the sight plug hole. Note the float-adjusting nut and lockscrew atop the bowl of this 4-bbl. Holley. If you have already set the float with a gauge and the fuel level doesn't reach the bottom of the sight plug hole, you should reset the float with the lockscrew and nut until the wet fuel level is correct. Best results are achieved with the adjustment being made while the engine is running at a normal idling speed on level ground.

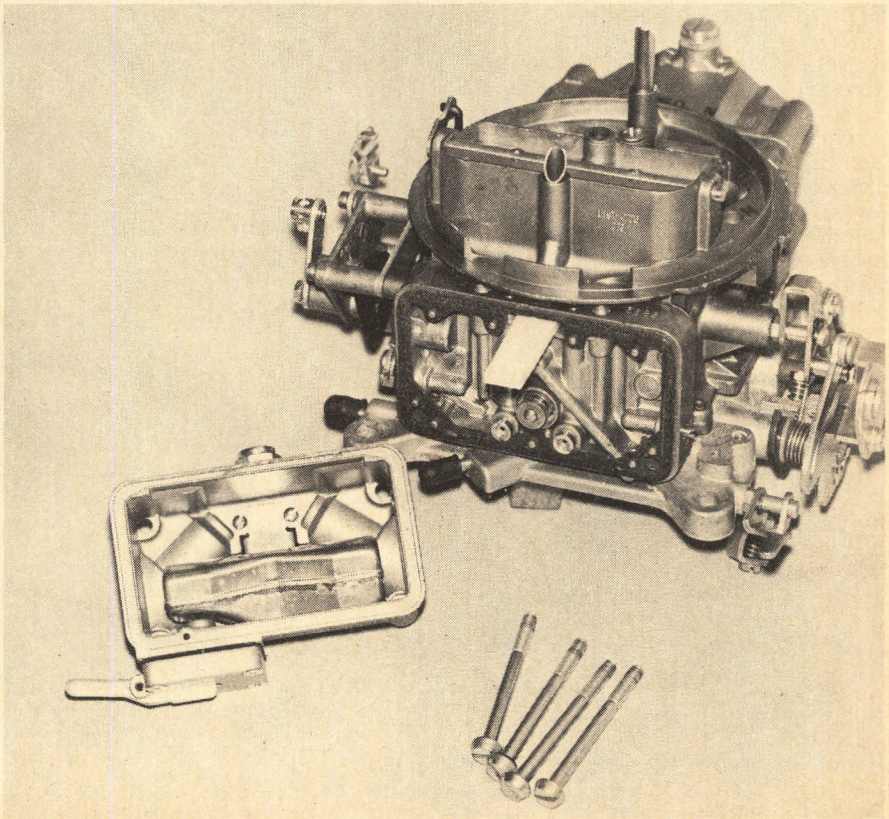
9. Four long screws hold the Holley 4-bbl. bowl in place. This is center-pivot float bowl, for racing.



7. Holley 4500 Accelerating Pump



8. Holley Sight Plug



9. Removing Holley Bowl

oil pressure comes up. But then you have the problem of getting fuel to the bowl after the car has been sitting awhile. This means that the driver must hold down a push-button bypass when starting. It can also be done the other way around with a switch to turn the pump off in case of carburetor flooding so that the engine can be cranked to clean it out without getting fuel. Some installations on new cars use an oil pressure switch in conjunction with a starting motor bypass. The pump operates only when there is oil pressure, or when the starter is operating. So don't be surprised if you turn the ignition switch on with the engine dead and the pump doesn't work. It's not supposed to.

There are many types of electric pumps around. They are designed mainly as pusher pumps so they must be mounted as close to the gas tank as possible and as low as possible so that they don't have to suck the gas uphill from the tank.

If you do decide to install an electric pump on your car, check the specifications of the pump carefully. Some of them do not have enough capacity and you will find your engine running out of fuel when it needs it the most. When installing an electric pump, it is best to bypass the mechanical pump that is on your car. If you don't bypass it then you will have to worry about two pumps because even though the mechanical pump is not doing any pumping, it still has a diaphragm that can rupture and leak gasoline. After installing an electric pump always test the pressure and volume compared to the old pump to be sure it is adequate.

FUEL FILTERS

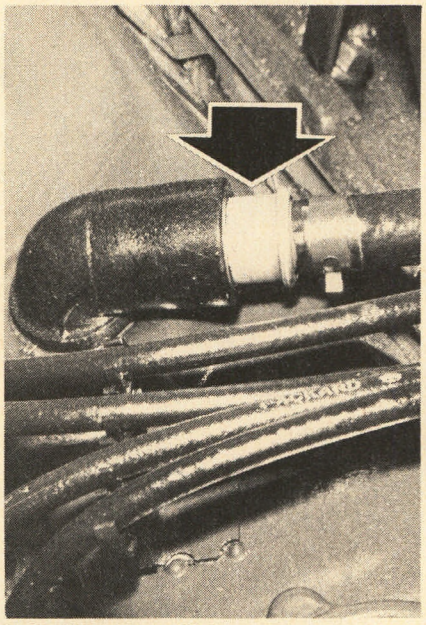
Fuel filters or screens can be in some surprising places on an automobile. As long as they work right you don't care where they are, but when they plug up and your car can only run a block without stuttering and stumbling, you have to find those filters in a hurry to clean them out. Regular cleaning and maintenance on filters will eliminate the trouble.

Some filters have an element that can be cleaned, such as a ceramic or metal screen, and others use a paper or fiberglass element that must be replaced. With a little experience you can tell by looking at an elment whether it should be cleaned or replaced. If in doubt, check the specifications for your car in the factory shop manual.

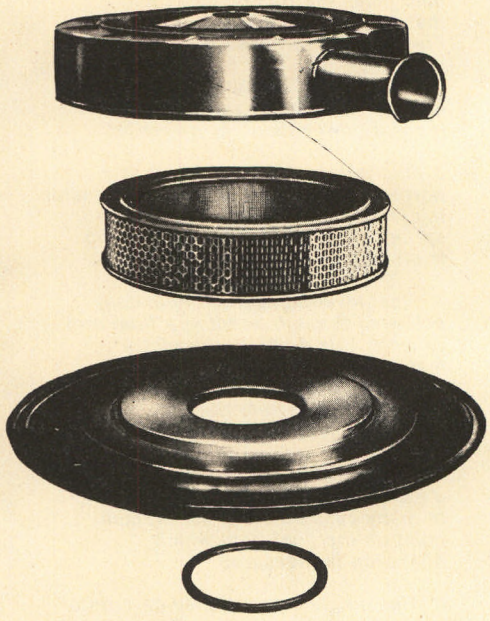
Many carburetors have a filter made out of bronze at the fuel inlet. You would think that this filter could be cleaned, but for some reason or other when the dirt settles in the pores of the bronze it stays there, and there really isn't much you can do except change it. How do you know when to change it? Well, the hard way to find out is to be going up a long hill at wide open throttle with a heavy load on your car and momentarily run out of gas. The easy way is to take the filter out, dip it in a bucket of solvent or gasoline and see if the solvent runs through it. If the solvent stays in the filter just like you had a cup of coffee in your hand, then you'd better throw it away and get a new one.

The next place you may find a filter is on the engine a few inches from the carburetor. If it's a glass bowl type, it will probably have a replacement element in it. The element however, could be made out of ceramic material. In that case, all you have to do is clean it and put it back in. The inline or can-type filter will also be found mounted on the engine between the carburetor and the fuel pump. This filter may be made of metal or plastic so that you can look into it to see if it's dirty. The best way to change these (whether they are transparent or not) is on a strict mileage basis, again, referring to the factory shop manual.

Some of the can-type filters are made specially for air-conditioned cars, with a bleed hole that bleeds fuel back to the tank. This is done to help prevent vapor lock which is caused by fuel vaporizing in the fuel lines before it reaches the carburetor. Vaporizing fuel, of course, will go right out through the bowl vent, thus leaving the engine with no fuel to run on. The fuel is actually boiling in the line, vaporizing at a rate faster than the

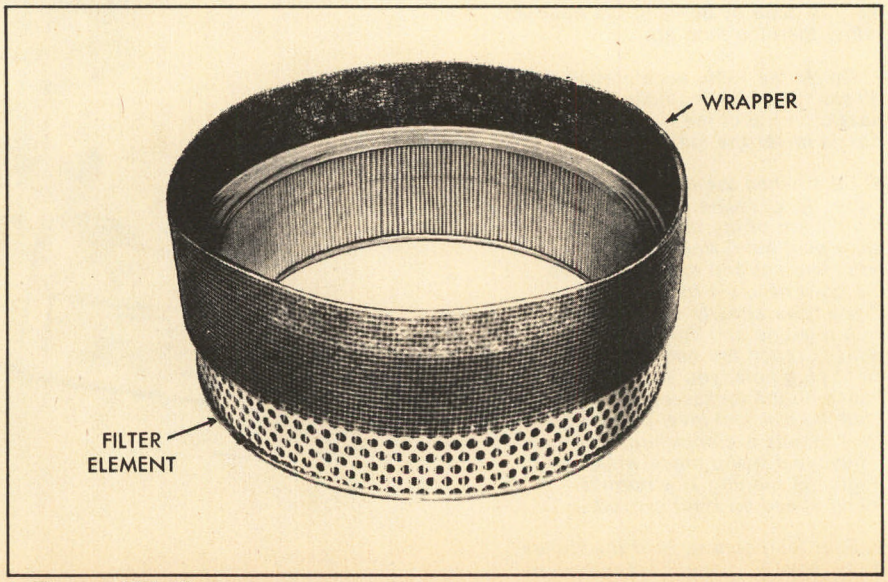


1. Cadillac Smog Valve



2. Paper Air Cleaner

3. Foam-Type Element



4. Element With Wrapper

5. Fuel Delivery Testing

1. If the engine doesn't idle right, don't be quick to blame the carburetor. Maybe the smog valve needs cleaning. On a Cadillac it's plugged into the right rocker cover.

2. Typical air cleaner used on General Motors cars. The gasket at the bottom goes between the cleaner and the carburetor, to prevent dirty air from getting in. In some cases, the bottom gasket is permanently held onto the air cleaner by metal tabs. Many air cleaners have additional filters inside them to trap oil that may come in through breather hoses. Don't forget to clean them, too.

3. In addition to wrapping snugly and evenly over the inner supporting element, a foam-type filter element must fit correctly within the metal air cleaner cover. If the foam is ripped or misshapen—or shows a tendency to crumble from age—it cannot filter effectively and should be replaced.

4. Some dry-type elements are encased in an outside wrapper usually made of a screened material. This wrapper is designed to keep the oil fumes from ruining the relatively fragile dry paper element. When removed from around the inner element, the outer wrapper may be washed, dried and replaced. One should never attempt to wash a paper element.

5. Accurate fuel delivery testing requires a stopwatch, a graduated container, and a long hose. Let the engine idle, and note time it takes to put out one pint. Compare results with specs or with other cars.

6. Typical heated air entry used on all late-model cars. System usually takes place of heat riser valve that was formerly found in exhaust.

7. This typical diaphragm-type AC fuel pump uses vacuum—as in an internal combustion engine—to alternately pull gas from the tank, then push it into the carburetor. The vacuum-producing motion of the diaphragm is provided by an eccentric attached to and driven off the camshaft. Note crimped cover, making rebuilding extremely difficult.

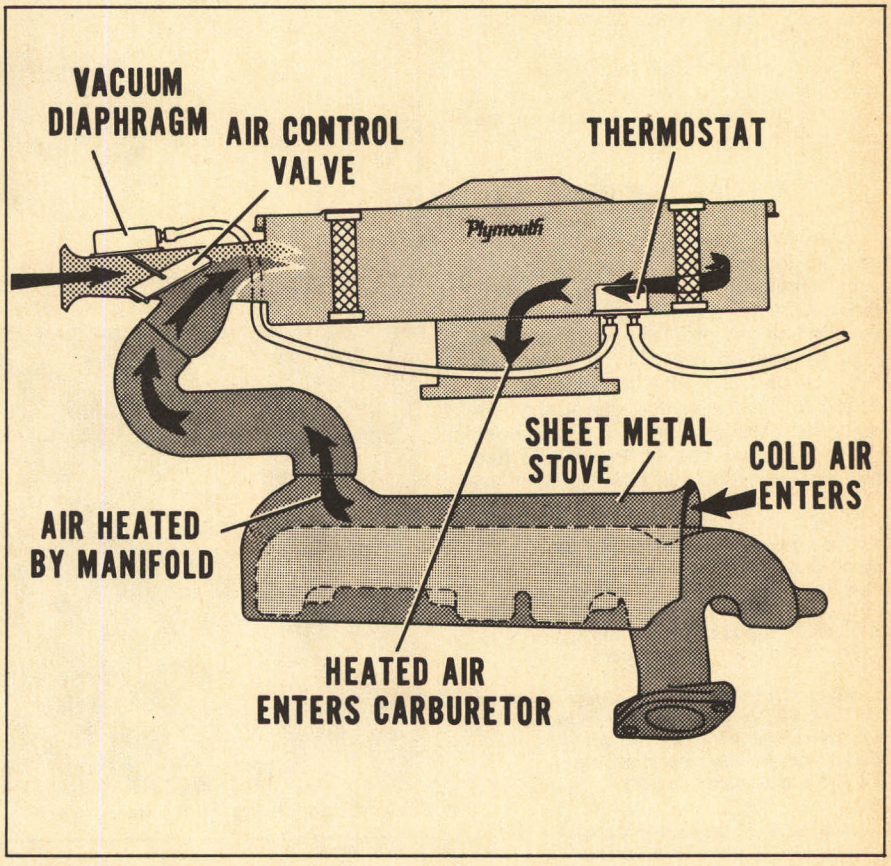
fuel pump can pump it. So the carburetor is receiving nothing at all except vapors—and it's kind of hard to run an engine that way.

That usually happens on a hot day in the middle of summer, on a long hill in heavy traffic. The only thing to do is get out and get some kind of liquid on the fuel pump and on the fuel lines even if you have to pour Coca-Cola on it. The liquid will cool the lines and the pump so that they will work again.

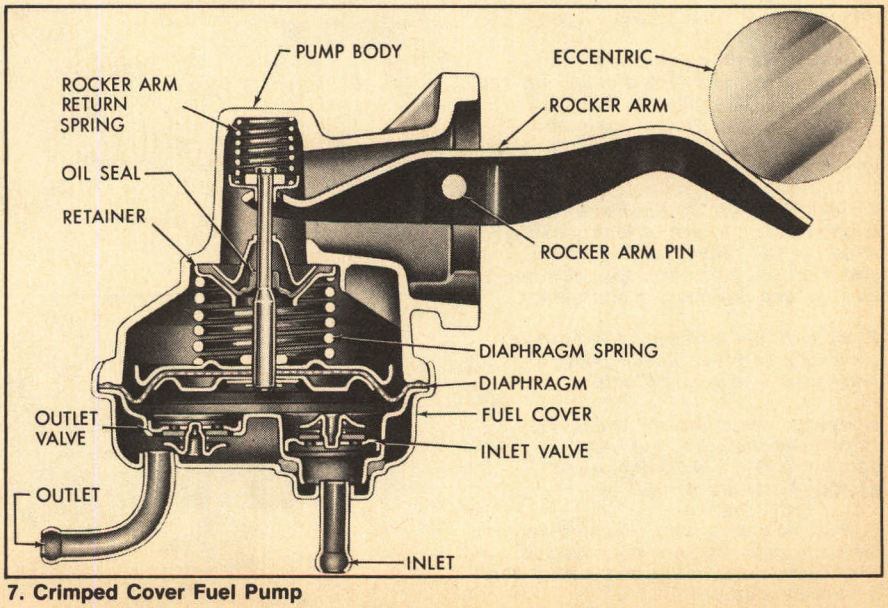
Fuel filters can also be found on the pump, either on the pressure side or the vacuum side. If they are part of the pump itself they are usually a glass bowl with maybe a changeable element or maybe not. With no element, the glass bowl merely acts as a sediment trap.

In the line from the fuel pump back to the tank there may also be a filter mounted somewhere on the frame-rail, and in the tank itself on the end of the pickup tube there is a filter made of fiberglass on every late-model car. These fiberglass filters on the pickup tube are designed to plug up in case any water gets in the tank, and they really do a good filtering job.

If you've ever seen a carburetor with fuel pump can pump it. So the carburetor is receiving nothing at all except vapors—and it's kind of hard to run an engine that way.



6. Heated-air Air Cleaner



7. Crimped Cover Fuel Pump

Fuel System

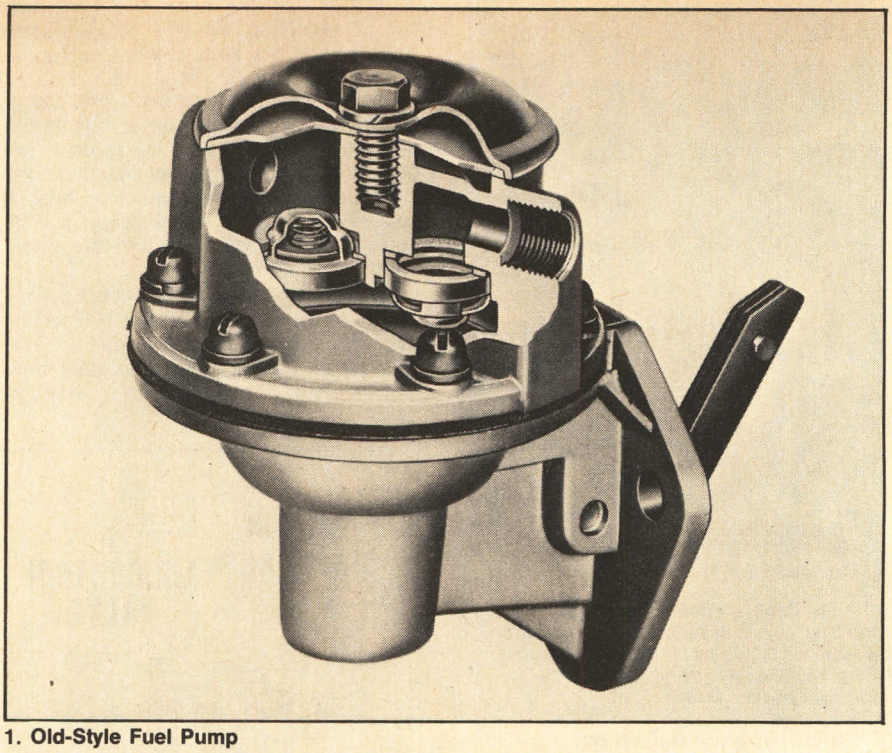
If you've ever seen a carburetor with water in it you won't forget it. A white residue forms created by a reaction between the water and the metal of the carburetor. It plugs up everything, and there's just nothing you can do except throw the carburetor away if the reaction has gone on for very long.

Filters are really important because of all the foreign matter that gets into the gas tank and comes from the tank itself. It's impossible to keep a gas tank full at all times. When it isn't full, water vapor can condense out of the air onto the sides of the tank causing rust. These rust particles will come through the fuel line and cause all kinds of trouble in the carburetor.

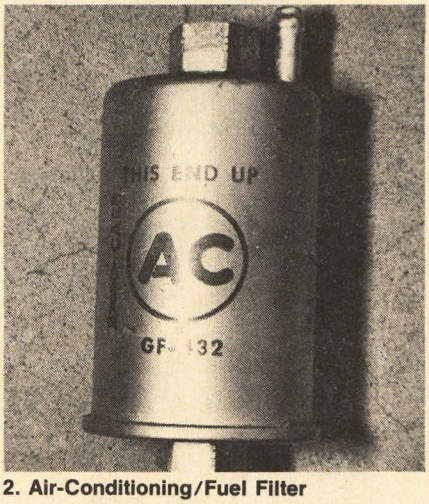
If you do get water in the fuel tank, you will have to remove the tank to clean it out. So let's take a look at how we do that next.

FUEL TANKS

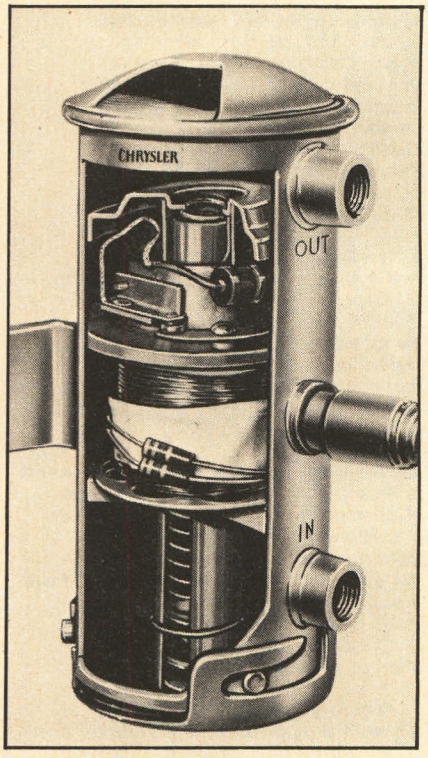
If you take fuel out of the tank, you have to let air in—so there has to be a vent somehwere on the tank, usually in the cap. If all caps were vented there wouldn't be any problem, but some tanks have a separate vent with a sealed cap. Put a sealed cap on a tank that is supposed to have a vented cap and you're going to have trouble. Your fuel pump might be strong enough to suck so hard that the walls of the tank actually col-



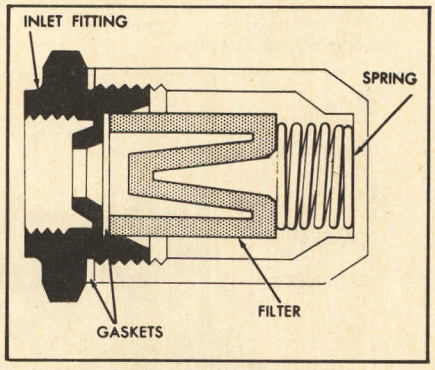
1. Old-Style Fuel Pump



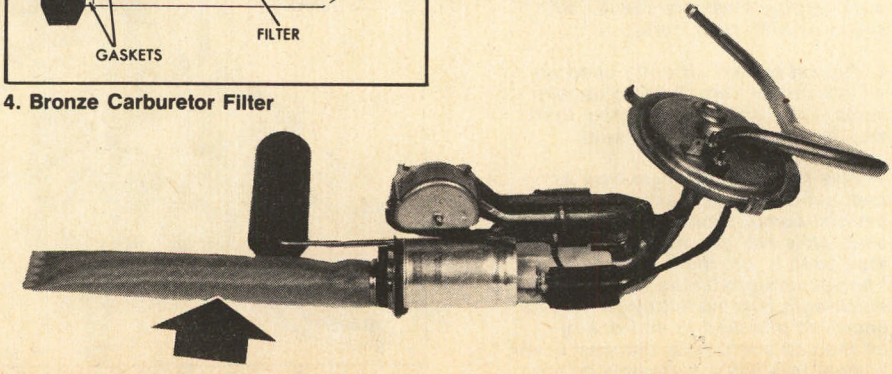
2. Air-Conditioning/Fuel Filter



3. Imperial Fuel Pump



4. Bronze Carburetor Filter



5. Vega Fuel Pump

1. Old-style fuel pumps could be taken apart and fixed with a kit that had new valves and a diaphragm.

2. Typical vapor-diverter filter used on General Motors cars.

3. When Chrysler put the smog pump on its '72 Calif. Imperials, they found out there was no room left for the fuel pump, so they used an electric. It's the old familiar Bendix.

4. A bronze filter—at the carb's inlet side—is usually a spring loaded device that seats the W-shaped filter against a small gasket. When plugged, it can cause agony.

5. Vegas use an electric fuel pump, combined with the tank pickup unit and gauge. Note fiberglass screen (arrow). It's necessary to protect the pump, but it can be a source of fuel starvation if it gets clogged.

6. Inlet fitting on '72 Rochester carbs is different; you have to look closely to see it. Old fittings seated on a shoulder, but new one seats at inner end to keep threads dry and clean.

7. Modern fuel tank package houses a combination fuel pickup, filter and gas gauge sending unit.

8. Special wrenches are available to get tank units out, but two screwdrivers will work just about as well if you are careful.

9. Most new cars have pressure-vacuum fuel tank caps that are supposed to keep vapors inside the tank so we don't have to breathe 'em.

lapse. But probably long before that happens the engine would run out of gas from fuel starvation. About that time somebody will take the cap off the tank to see if there's any gas and of course that let's the air in. Then the fuel pump will pump until it reaches the point where there is a vacuum in the tank again.

If you are in doubt about the kind of cap your tank is supposed to have, crawl under the car and see if there is an actual vent coming off the tank somewhere. If you see a vent tube then you can be pretty sure that the tank is supposed to have a sealed cap. Also if you ever take a cap off a tank and hear a rush of air into the tank, you can be pretty sure it has a sealed cap on it but it should have a vented cap.

If you have been unlucky enough to get water in the gas tank, it will plug up the fiberglass filter that is used on the end of the pickup tube on late-model cars. Ordinarily this means removing the tank because there is no tank drain on most cars manufactured nowadays.

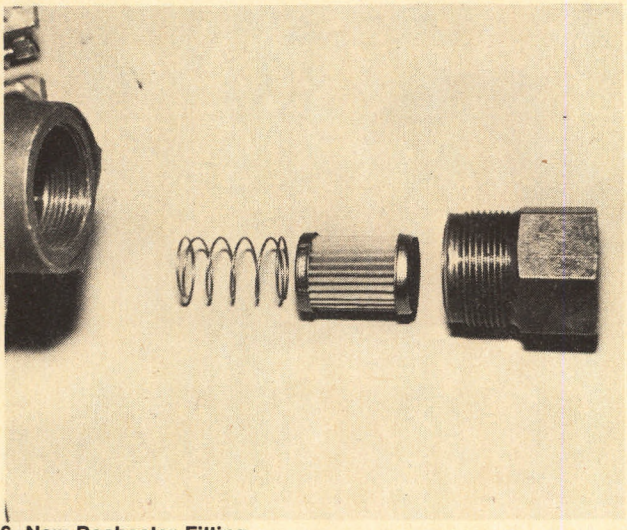
Always siphon a tank completely dry before attempting to remove it, then remove all lines, wires and filler neck braces, and put some blocks up under the tank to hold it while you remove the two long straps that hold it against the car. Then remove the blocks and lower the tank.

You can clean the tank out by pouring solvent in through the filler neck opening and through the opening for the tank gauge unit. Tank gauge units usually use a locking ring which takes a special wrench, but with a little ingenuity and some careful prying you can usually get the gauge unit out. Don't pry on the pickup tube under any circumstances because it's very fragile. Tank gauge units should always be handled with extreme care so as not to bend the gauge arm or break any of the soldering loose.

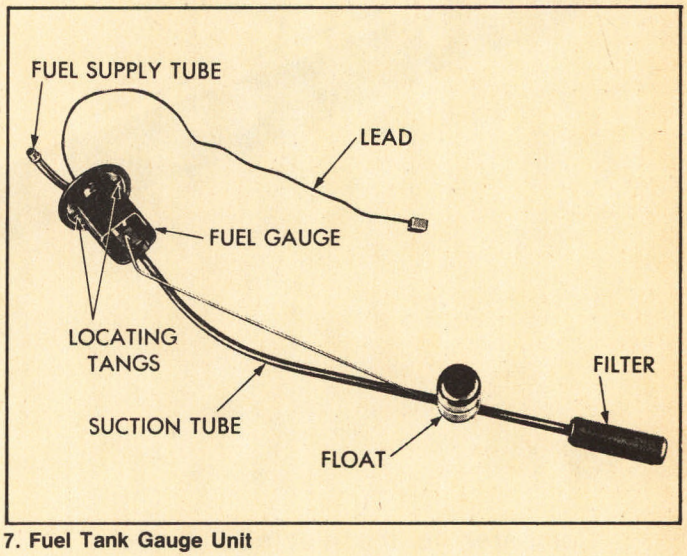
LINES AND FITTINGS

It used to be customary to have a steel line running from the tank up to a point on the frame near the fuel pump, then a flexible hose went across to the pump and another steel line went from the pump to the carburetor. Some later cars made the steel line jump off the frame and go through a long arc and attach directly to the fuel pump so that the flexible line was unnecessary. Still later models use a combination of neoprene rubber and steel lines. Copper line should never be used in a fuel system because it sometimes can have a reaction with the gasoline.

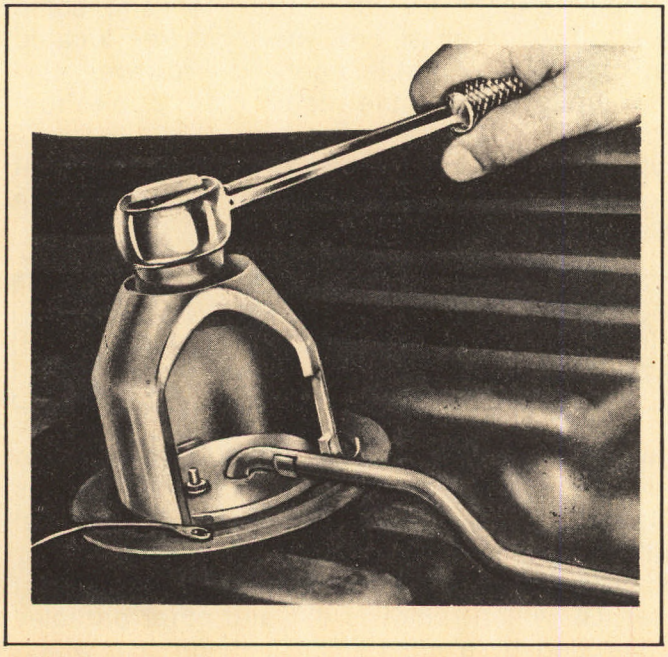
Any flexible fuel line should be inspected from time to time to be sure it is not cracking; other than that, there is no maintenance required on fuel lines. Whenever you replace a line be sure that the fitting is matched. Just because two fittings will screw together does not mean that they are going to make a good seal. Several different types of brass fittings are in common use on automobiles today. If you have to replace a fitting be sure that the new one is exactly the same both inside and out.



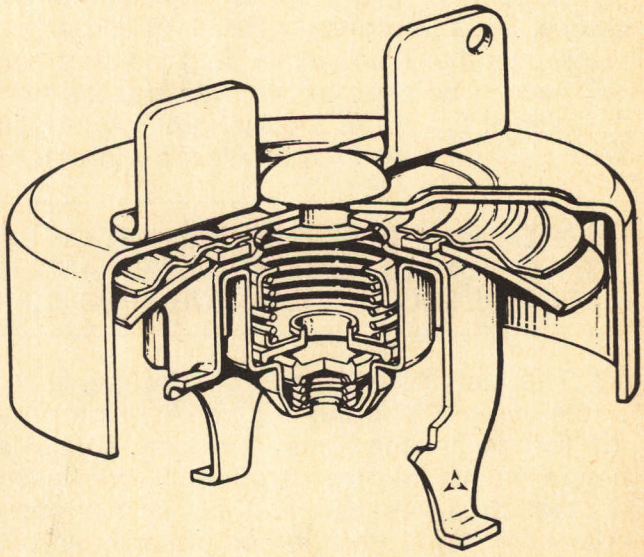
6. New Rochester Fitting



7. Fuel Tank Gauge Unit

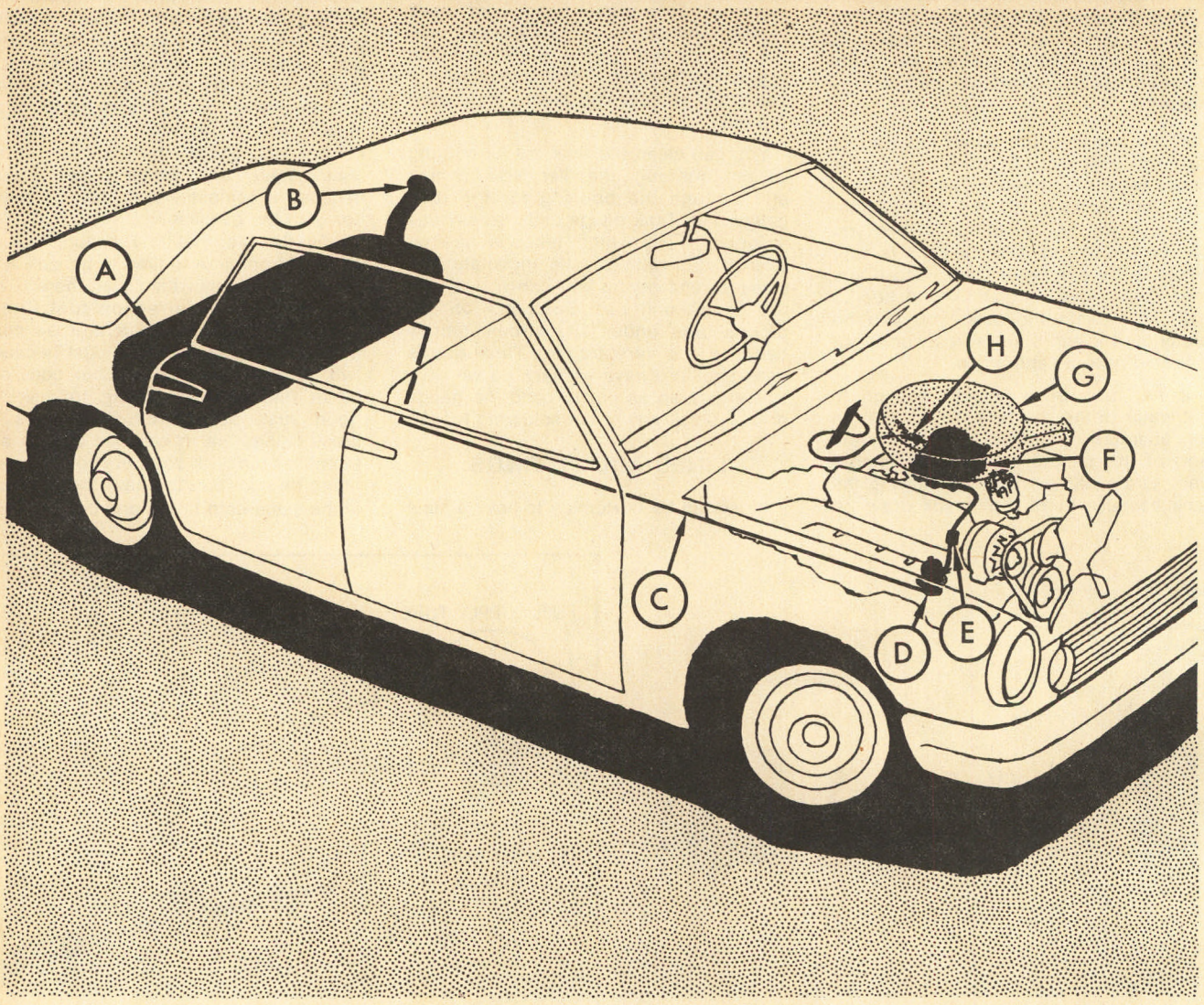


8. Removing Tank Unit



9. Pressure-Vacuum Tank Cap

TROUBLESHOOTING THE FUEL SYSTEM



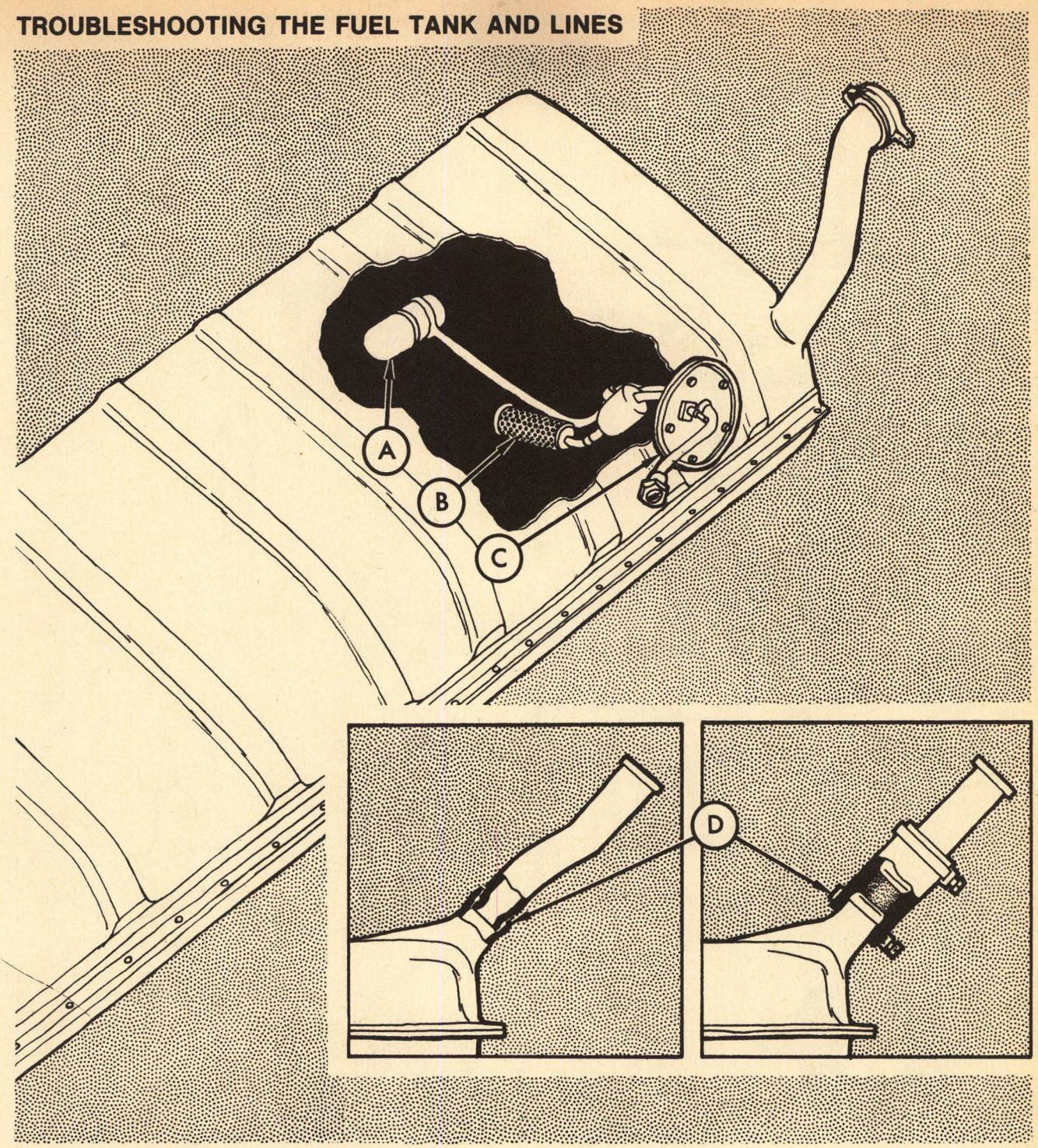
Compared to the electrical portions of the automobile, the equipment for storage and delivery of gasoline to the engine is quite simple. Except for the carburetor and some additional equipment installed on late-model cars to reduce emissions, the logic tree located in the back of this book is sufficient for most fuel system problem-solving. However, this chapter goes into greater detail on all parts of the fuel system so the reader can troubleshoot problems other than simple start/no start conditions.

As can be seen in the drawing, the fuel system contains a number of parts. Located at the rear of the car is the fuel tank (A), which contains the supply of fuel for the car. It has a filler cap and a vent (B) to allow air to enter the tank as fuel is withdrawn.

NOTE: WITH THE INTRODUCTION OF EVAPORATIVE SYSTEMS FOR EMISSION CONTROL, VENTING IS NO LONGER HANDLED IN THIS MANNER ON LATE-MODEL CARS. SEE THE SHOP MANUAL FOR SPECIFIC INSTRUCTIONS.

The fuel line (C) runs from the gas tank forward to the engine area, where it connects to a fuel pump (D) on the engine. At some point along this line, either before or after it reaches the fuel pump, there may be some sort of a filter (E) to remove dirt particles from the fuel before it goes into the carburetor. After leaving the fuel pump, the line goes to the carburetor (F), which mixes fuel and air in the correct proportions for burning in the combustion chambers. On top of the carburetor is an air filter (G), which removes dirt and other particles from the air. The action of the carburetor is controlled by a mechanical linkage (H), which runs from the carburetor into the driver's compartment and to the accelerator pedal.

TROUBLESHOOTING THE FUEL TANK AND LINES



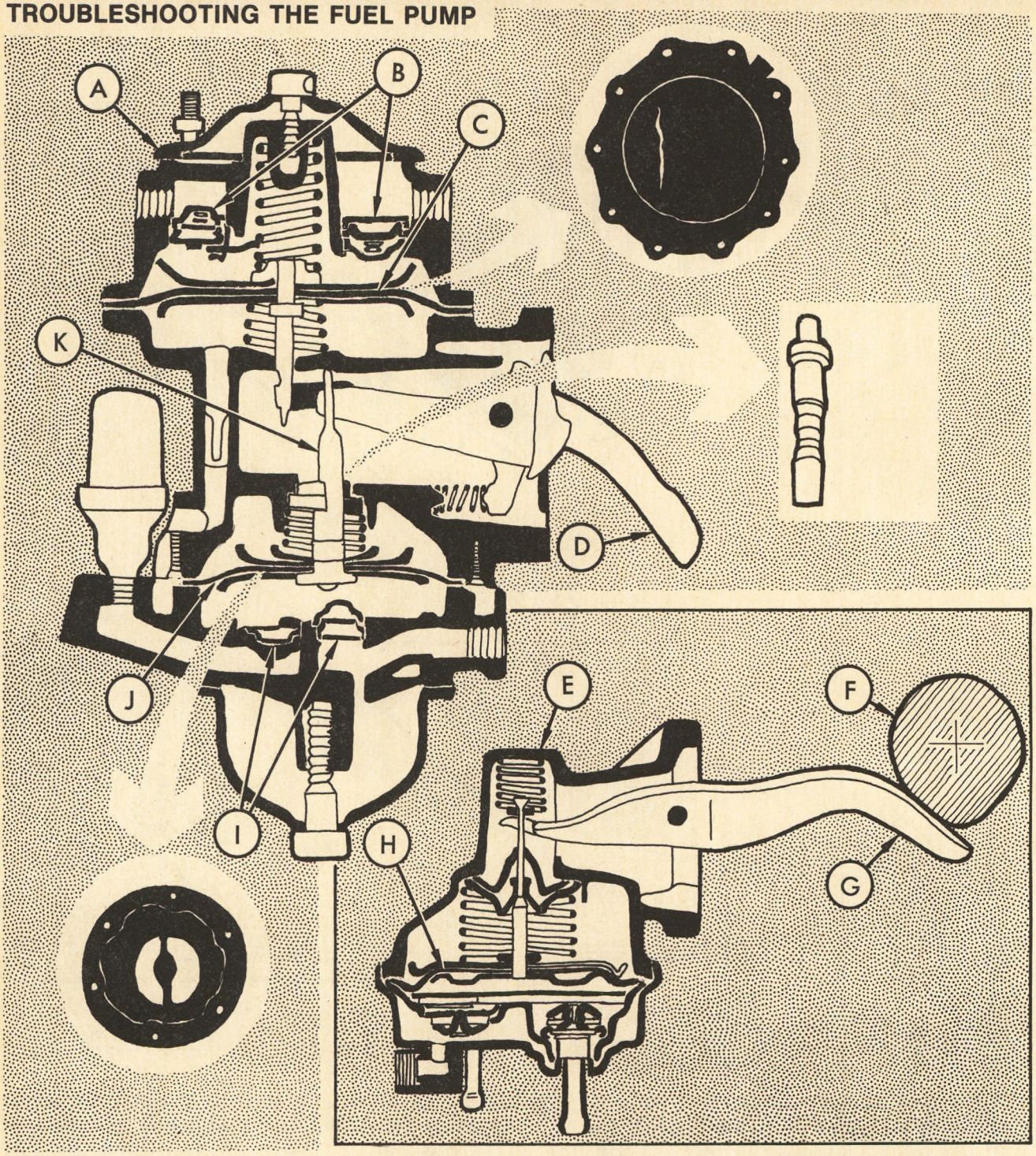
There is very little that can go wrong with the fuel tank. The tank is a metal container with a pickup unit (C) suspended in the top center of the tank. Along with this pickup is a float (A), which signals the level of the fuel to the gas gauge. These units are not normally repairable. They can be replaced, although removal of the fuel tank is required in many cases.

Actual leakage of fuel from the metal portion of the tank is rare, but leakage can occur around the attachment point of the filler neck (D) to the tank. In such cases, the repairs should be done by a qualified mechanic. Fuel flow stoppage, as outlined in the fuel system logic tree in the back of the book, is usually associated with the filter or screen (B) on the fuel pickup or inside the fuel line.

Indications of fuel leakage are the smell of gasoline around the bottom of the fuel tank and lines or discoloration caused by gas leaking down the frame of the car. On new cars with evaporative control systems, there may be several lines leading to and from the gas tank or other containers which hold gas vapors. See the shop manual for your car for specific information on troubleshooting and repairing these evaporative control systems.

TROUBLESHOOTING THE FUEL SYSTEM

TROUBLESHOOTING THE FUEL PUMP



The normal fuel pump used on modern automobiles is the mechanical type (E). Some common mechanical problems that can occur in a fuel pump are:

- Worn vacuum valves and seat—diaphragm type (B)
- Punctured vacuum diaphragm (C)
- Punctured fuel diaphragm (J)
- Worn fuel valves and seats (I)
- Worn pull rod (K)
- Worn linkage (D)

Without the fuel pump to pull gas from the tank to the float bowl of the carburetor, the engine would quickly run out of fuel and stop running.

Most fuel pumps work by mechanical action through a lever (G) which contacts a portion of the camshaft (F). As the camshaft rotates inside the engine, the lever is moved up and down by the camshaft. This lever action operates a rubber diaphragm which creates suction, pulling fuel through the lines from the tank. On one stroke of the diaphragm (H), fuel is pulled into the pump through a one-way valve. On the other stroke of the pump, the fuel, which cannot return to the tank through the one-way valve, is forced out of the fuel pump to the carburetor.

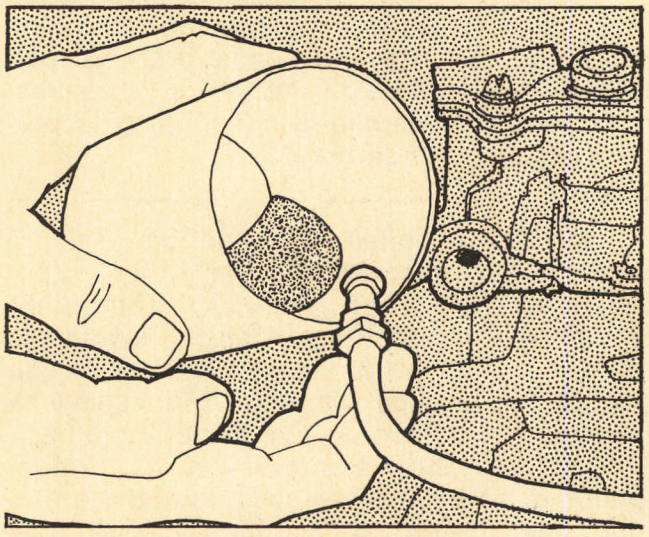
On many fuel pumps, there is also a separate section (A) devoted to producing a vacuum to operate windshield wipers.

NOTE: FUEL PUMPS THAT CREATE VACUUM TO RUN WIPERS ARE COMMON ON OLDER AUTOMOBILES BUT NOT ON LATE MODELS.

Many modern fuel pumps are designed to be non-repairable. These types have a crimped shell rather than a bolted shell and must be replaced if they go bad. Those types with a bolted shell can be repaired. The most common problems are a ruptured fuel diaphragm (H) or (J) or a lever (G) which is worn to such a point that it is not capable of delivering a full stroke. If the fuel pump is removed to check the lever for wear and the engine is the type that uses a small pushrod as a connection between the cam and the fuel pump, carefully check the pushrod for wear.

Carefully check all connections at the fuel pump. A leak in a line leading to or from the pump will reduce pump pressure. Steel lines can develop cracks from vibration and flex lines can rot. Below are three checks you can perform to further test the fuel pump for proper operation.

FUEL PUMP VOLUME TEST



The method for checking the amount of fuel being delivered by the pump is the same as outlined in the fuel system logic tree. Remove the inlet fuel line from the carburetor. Use a container of reasonable size. Position the line so that the fuel that is pumped into the container will not spill on any hot part of the engine.

WARNING: WHEN WORKING WITH DISCONNECTED FUEL LINES, A POTENTIAL FIRE HAZARD EXISTS. DISCONNECT THE HIGH-TENSION LEAD (THE CENTER LEAD) FROM THE IGNITION COIL TO PREVENT THE ENGINE FROM STARTING.

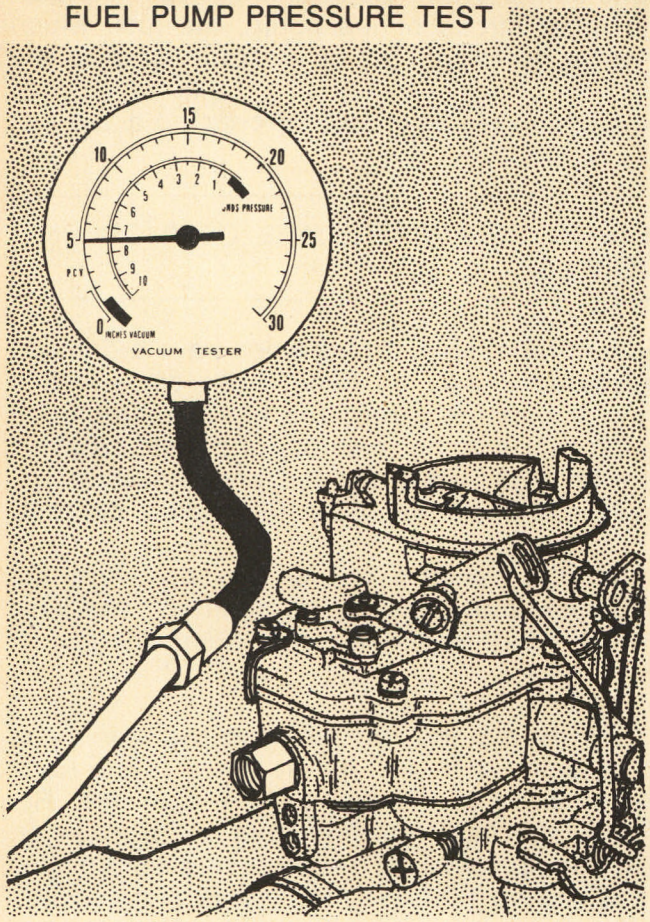
Crank the engine over while watching the fuel line (you will need a helper here). Most automobile pumps are capable of filling a pint container in 30 seconds.

NOTE: MANY HIGH-CAPACITY PUMPS ON MODERN AUTOMOBILES WILL DELIVER CONSIDERABLY MORE THAN 1 PINT IN 30 SECONDS. BE SURE TO USE A CONTAINER CAPABLE OF HOLDING AT LEAST A QUART.

Measure the elapsed time and compare it to the manufacturer's specifications (see the shop manual). While the container is filling, submerge the end of the line in the fuel to see if any air bubbles are present. If there are bubbles, this is an indication of air leaks in the pump or in the lines. If your engine is equipped with a metal line between the fuel pump and the carburetor, you may have to attach a piece of flexible line to the end of the metal line in order to submerge it in the container. If the pump volume is low (pump puts out ½ pint or less in 30 seconds), the pump may be bad or there may be a restriction in the line leading from the fuel tank to the pump. Check the line carefully for signs of leaks. Then go on to the second fuel pump check: inspecting the pressure output of the fuel pump.

TROUBLESHOOTING THE FUEL SYSTEM

FUEL PUMP PRESSURE TEST



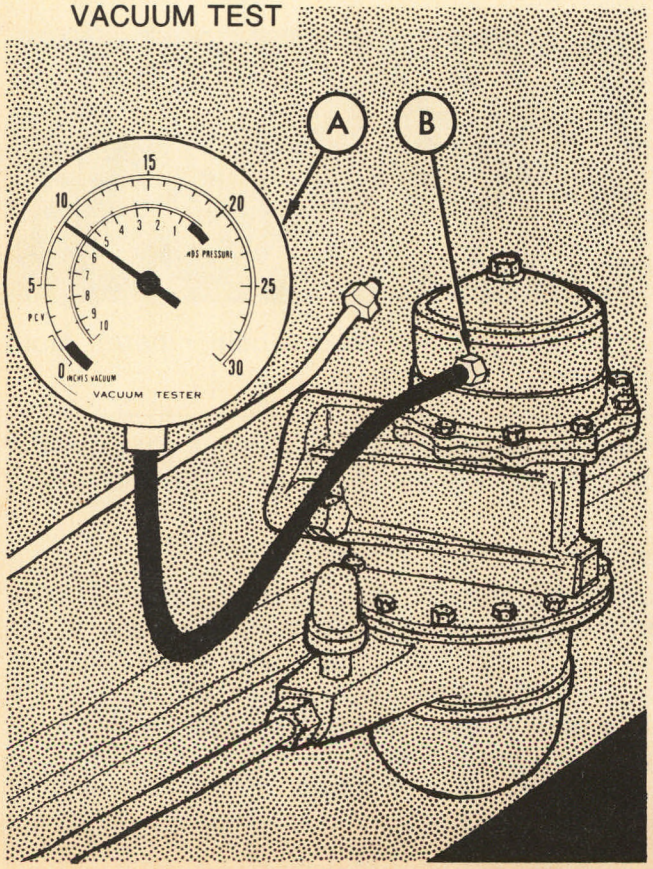
The vacuum gauge can be used to check the pressure output of the fuel pump by employing its pressure scale. Remove the fuel line at the carburetor and connect the vacuum gauge to the line. Crank the engine over and watch the gauge. The gauge should indicate the following:

- V-6's = 3.0/4.5
- Ford = 3.5/6.5
- Pinto = 3.5/4.5
- Chevy V-8, pre-1970 = 5.0/6.5
- Chevy V-8, after 1970 = 7.0/8.5
- Vega = 3.0/4.5
- Chrysler = 3.0/8.5

For all other cars, you should consult the shop manual.

On older model fuel pumps, the pressure will hold for several minutes after the engine stops, but modern fuel pumps are equipped with a pressure bleed valve which vents pressure when the engine is not running to prevent flooding the carburetor.

VACUUM TEST

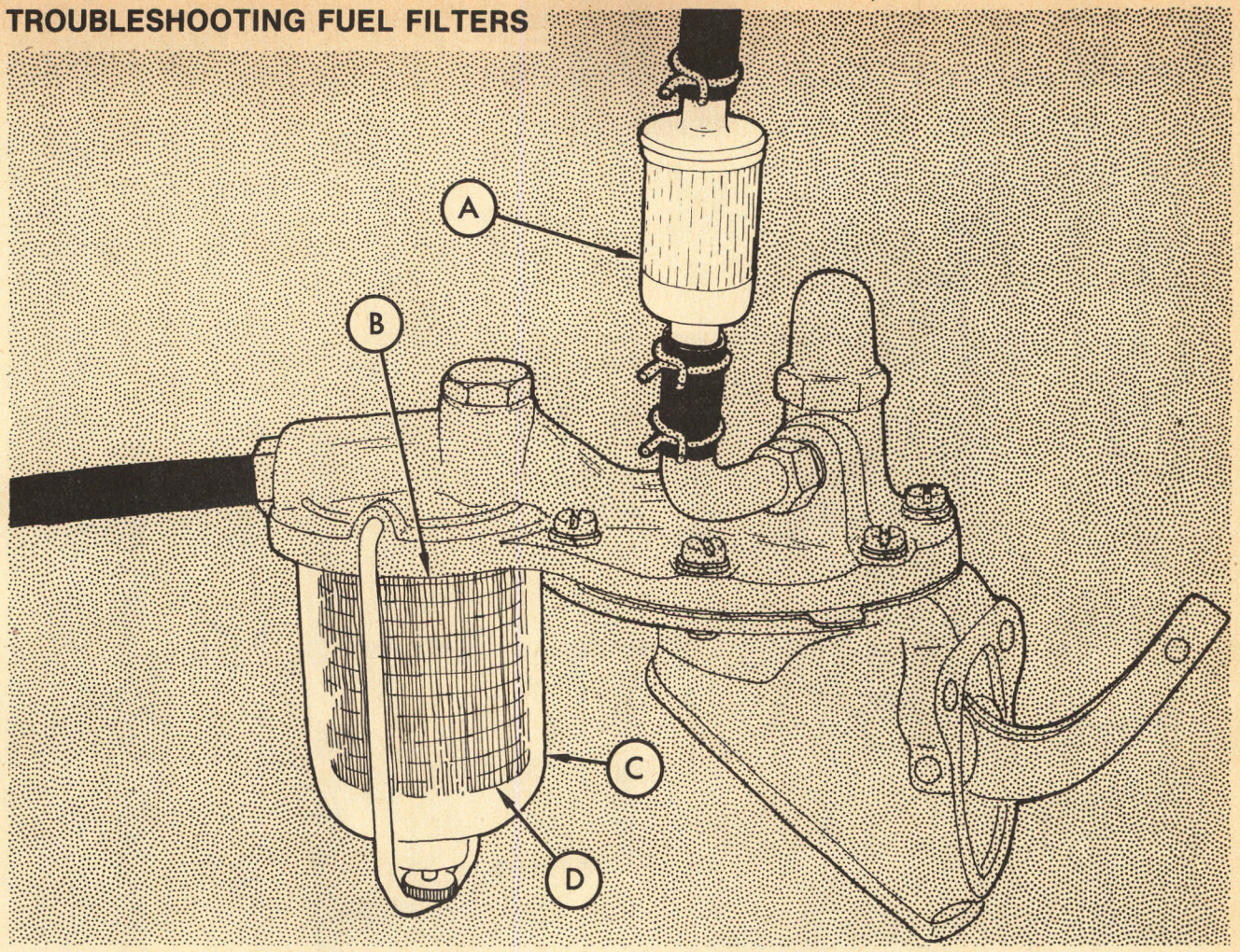


On automobiles with vacuum-assisted windshield wipers, a booster may be incorporated on the fuel pump. (Automobiles equipped with electric windshield wipers will not have this type of vacuum booster on the fuel pump.) Pumps with such a booster look like two fuel pumps, one on top of the other.

To test the vacuum side of the fuel pump, disconnect the vacuum line at the vacuum inlet (B—see the shop manual for location) and connect the vacuum gauge (A) to the inlet. Start the engine and run it at a fast idle (1,000 rpm). The gauge should show a reading of 8 to 10 inches of vacuum. Stop the engine. The vacuum reading should fall off slowly.

Rapid decline of vacuum indicates a leak in the pump or vacuum system. If windshield wiper action in vacuum-powered wipers is sluggish, the check shows a rapid reduction of vacuum after the test or the test fails to provide the proper vacuum reading, the vacuum section of the fuel pump is bad or there is a leak in the lines. Consult the shop manual for information on repairing or replacing the vacuum booster section or the entire fuel pump.

TROUBLESHOOTING FUEL FILTERS

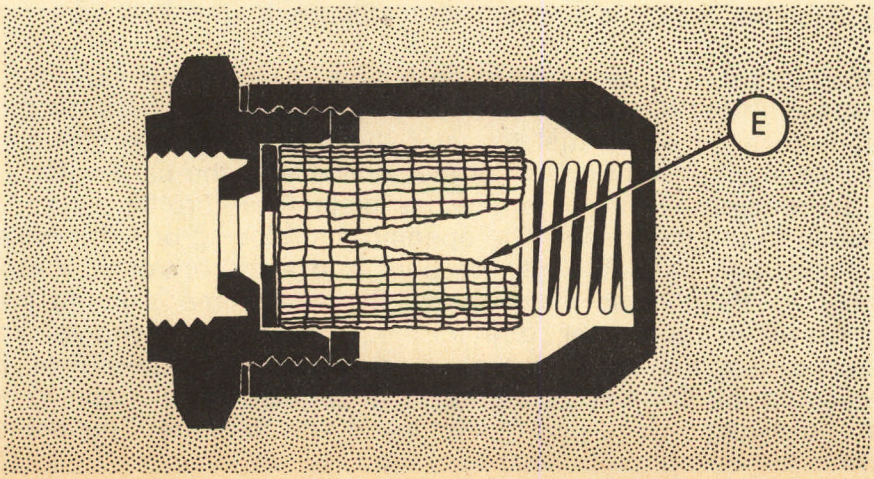


Fuel filters generally come in two types: an in-line filter (A), which is put into the line between the fuel pump and the carburetor; and a sediment-bowl kind (B), which is part of the fuel pump housing. In either case, clogging by dirt or sediment can block the flow of fuel to the engine.

In-line filters are designed to be a throwaway item. The cost of replacement is low, and if clogging is suspected, the filter should be removed and a new one installed.

The sediment bowl is a glass bowl (C) held in place on the fuel pump by a clamp and hold-down screw. Inside the bowl is a filter element (D) which, in most cases, is washable in gasoline.

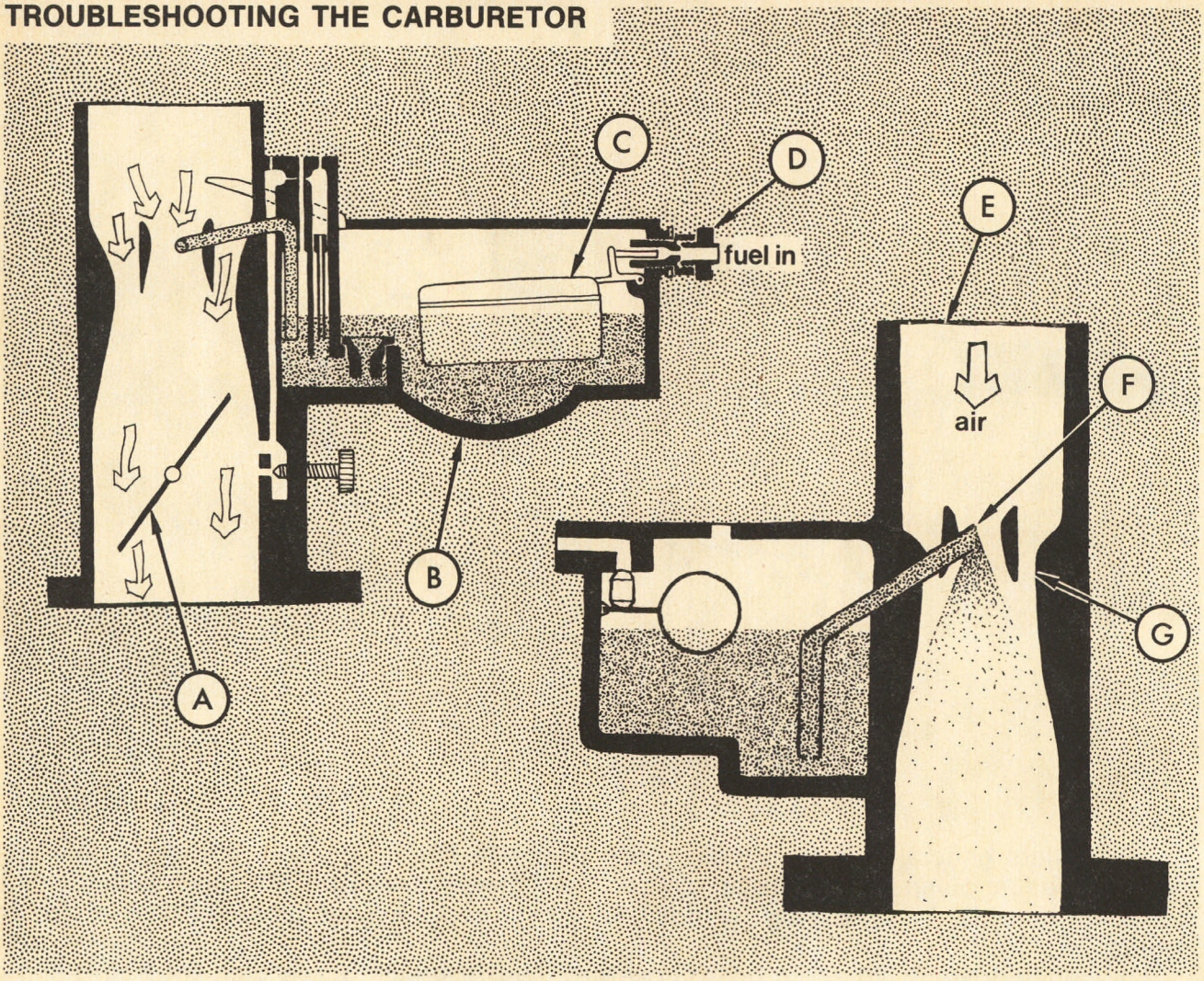
NOTE: USE CAUTION WHEN REPLACING THE SEDIMENT BOWL FILTER. THE GASKET MUST PROVIDE A PERFECT SEAL TO PREVENT GAS LEAKAGE.



Another washable fuel filter (E) is often found in the fuel inlet fitting of many modern carburetors. This is a short filter of fine brass mesh which will filter out large particles of dirt and grit to prevent them from entering the carburetor. In many cases, the inlet fitting on the carburetor must be removed to get at the filter element. Check the shop manual for information on cleaning or replacement.

TROUBLESHOOTING THE FUEL SYSTEM

TROUBLESHOOTING THE CARBURETOR

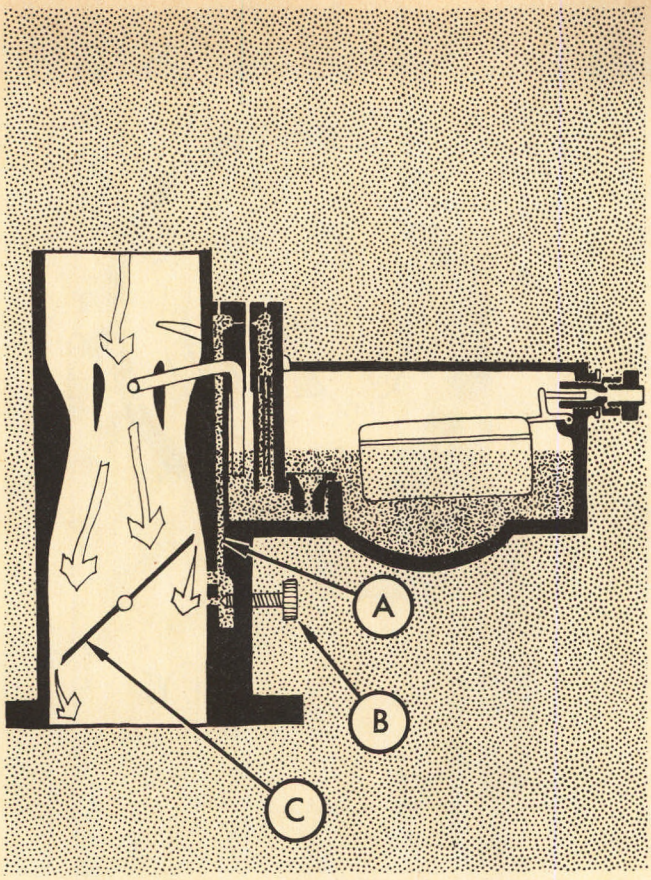


The most important single element in the fuel system is the carburetor. Its job is to provide the engine with the proper air/fuel ratio for a wide range of operating conditions.

The carburetor operates on a simple physical principle. Air drawn into the engine by the downward suction of a piston in a cylinder enters the top of the carburetor bore (E). As the air travels downward in the bore, it passes through a slight narrowing of the bore known as the venturi (G). As the air passes through the venturi, it speeds up. This speedup of the air causes a slight drop in pressure in the venturi. The drop in pressure pulls gas from the float bowl (B) through a nozzle (F) into the bore of the carburetor. At this point, the fuel mixes with the air, forming a fine spray of atomized particles. This air/fuel mixture passes through the carburetor into the intake manifold, which distributes the mixture to the cylinders for compression and burning.

As pressure is reduced in the venturi, it causes fuel to be pulled from the float bowl (B). The falling level of the gas causes the float (C) to drop. The float controls a valve called the needle and seat (D), which opens to allow more fuel to enter the float bowl from the fuel pump. This self-metering system keeps a constant supply of fuel available to the carburetor.

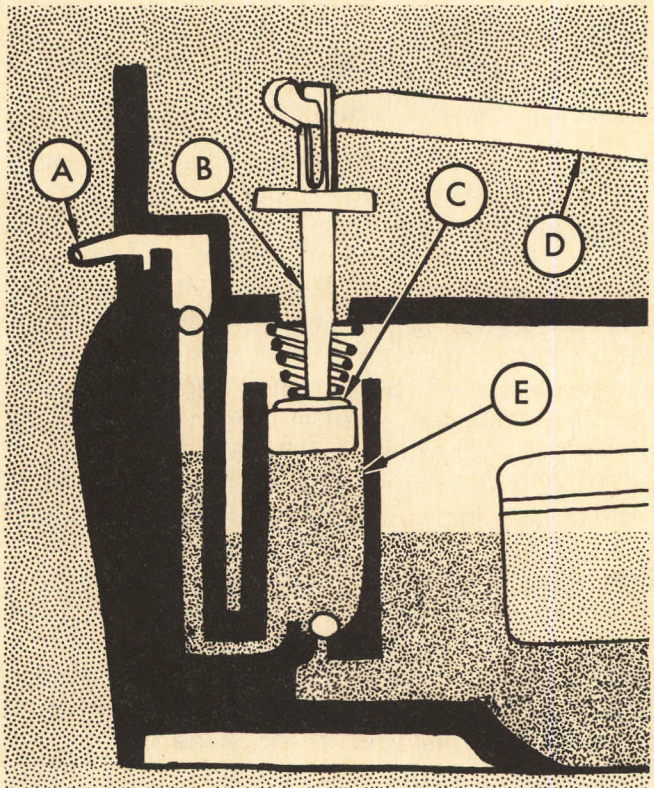
Below the point where the fuel enters the bore is a movable plate. This throttle plate (A) is controlled by the linkage attached to the gas pedal. The opening and closing of the throttle plate controls the amount of air that can pass through the bore and also controls the fuel that is drawn into the air stream. As the throttle plate opens, the air volume entering the intake manifold increases and draws in more fuel, due to the increasingly low pressure created by the venturi. This action causes the engine to speed up and deliver more power. If the throttle plate closes, the amount of air that can enter the engine drops, causing a lessening of the partial vacuum of the venturi, and less gas is pulled into the bore. This is the basic metering system that controls the overall carburetor operation.



When the engine is running at idle speed or with only slight foot pressure on the gas pedal, the throttle plate is nearly closed. This reduces the intake of air below the point where it will pull fuel from the float bowl through the main metering nozzle. A separate fuel path called the idle circuit (A) is necessary. When the engine is running at idle, the vacuum or low-pressure area is not at the venturi, but is most strongly felt below the throttle plate (C). By providing another route for gas to enter the carburetor bore below the throttle plate, sufficient fuel can enter the engine for idle and low-speed operation.

Fuel is drawn through a passageway from the float bowl by the low pressure to a point below the throttle plate. There is an external adjusting screw, called the idle mixture screw (B), located on the outside of the carburetor near the base. This screw regulates the amount of fuel available at the port. Another adjustment screw, the idle speed screw, is also located on the outside of the carburetor. The idle speed screw controls the position of the throttle plate over a small range to adjust the amount of air that is allowed to enter the engine.

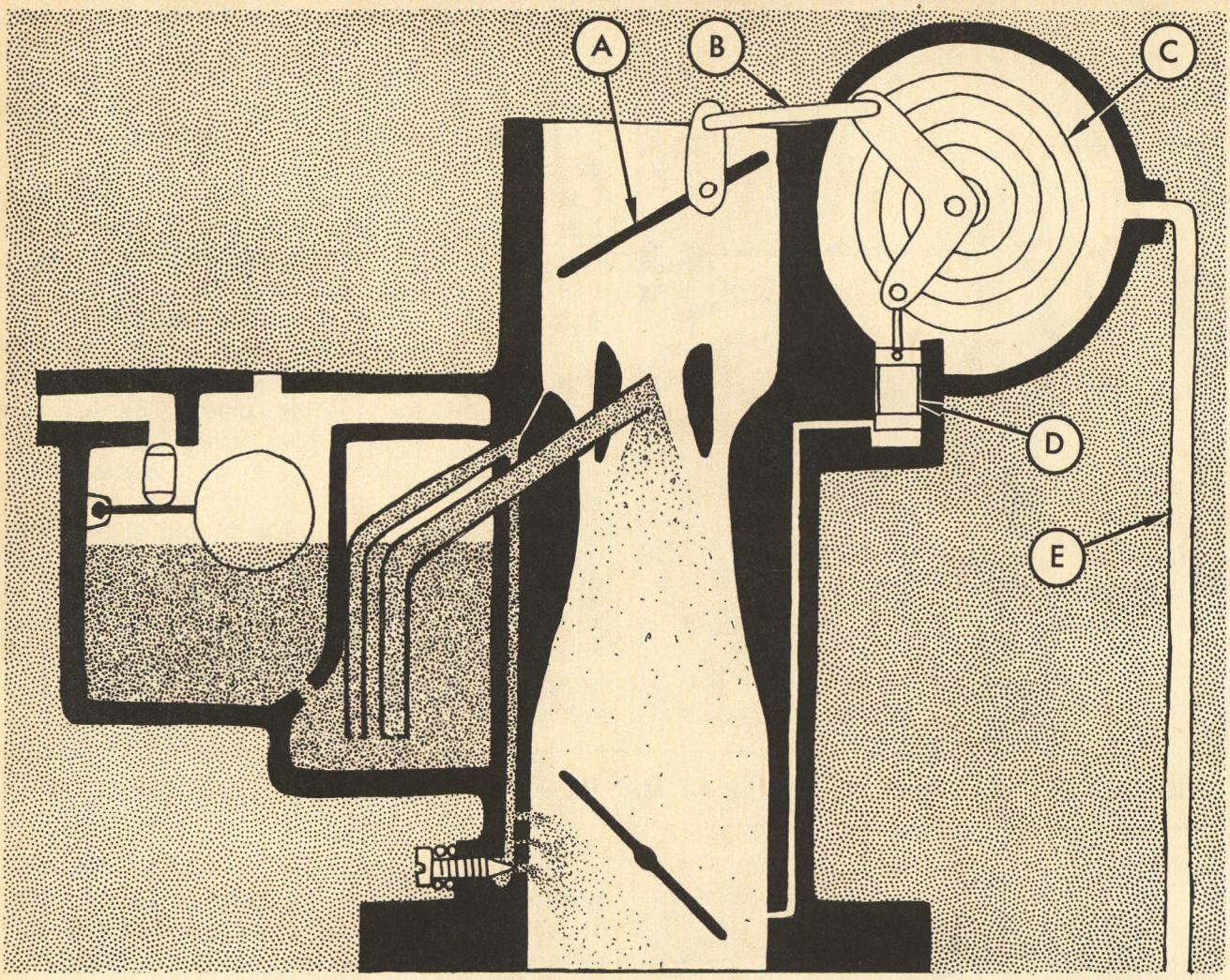
NOTE: THE IDLE SPEED ADJUSTMENT MAY ALSO BE CALLED THE THROTTLE STOP.



In some carburetors, a slightly different system is used, one that allows the throttle plate to close completely and routes air through a passageway around the plate to provide idle air flow.

When the throttle is opened suddenly while the engine is idling or running at a steady speed above idle, the rush of additional air into the engine upsets the balance of air to fuel. The fuel, being heavier, cannot respond as quickly as the air. To offset this, another system, called the accelerating pump (B), is used. This consists of an external linkage (D) attached to the throttle and a plunger (C) inside a well (E) filled with gas from the float bowl. When the gas pedal is depressed, the action of the linkage forces the fuel in the accelerator pump well to shoot out of a port (A) into the air stream in the bore. This momentary addition of fuel corrects the imbalance and permits the engine to function normally until the increased suction in the venturi starts drawing more gas from the main nozzle.

TROUBLESHOOTING THE FUEL SYSTEM



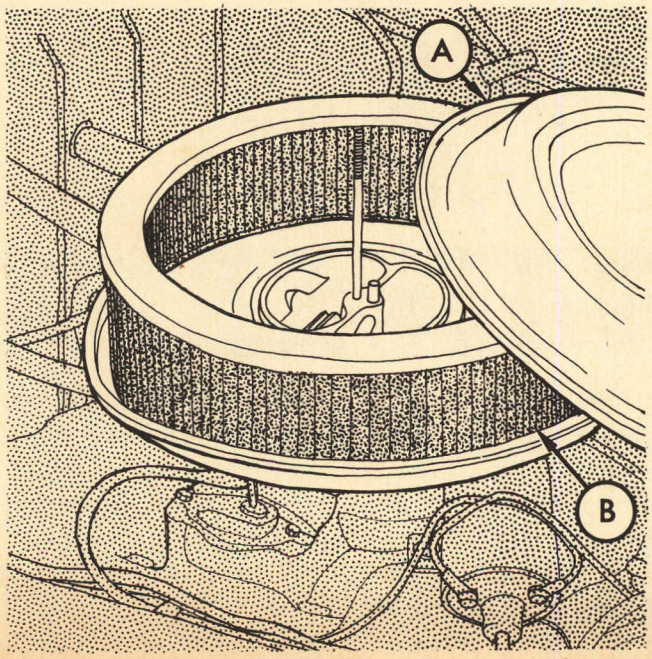
At the top of the carburetor bore is another plate which looks much like the throttle plate. This is the choke plate (A). The choke is used to help the engine start when it is cold and keep it running until the engine warms up to operating temperature.

When the engine is cold, the fuel tends to drop out of the air/fuel mixture and cling to (condense on) the interior surfaces of the intake manifold and the carburetor. This disturbs the balance of air to fuel. To prevent this problem from affecting the engine, the choke plate closes, cutting down on the intake of air. This creates a mixture richer in fuel and aids starting. The choke can be manually or automatically operated. Some older cars and trucks may have a manual choke controlled by a knob on the dashboard, but modern vehicles have an automatic choke. The automatic choke shown has a choke plate (A) which is connected to the thermostatic coil spring (C) by a linkage (B). On the other side of the linkage is a choke piston (D). Connected to the body of the choke housing is a tube (E) that runs to the heat stove.

Closing the choke is accomplished by the thermostatic coil (C). The spring is made of a material which relaxes when heated. To set the choke on most cars (when starting a cold engine), depress the gas pedal firmly, all the way to the floor. This positions the linkage to shut the choke plate in the carburetor bore. It also slightly increases the idle speed for cold engine warmup. While the engine is starting, the choke remains closed to block off most of the incoming air. This provides the engine with a rich fuel mixture. As soon as the engine starts, the choke must be opened partway to allow enough air for idle operation. The choke piston does this. By using the vacuum in the lower part of the throttle bore, the choke piston is pulled down, moving the linkage to open the choke slightly. As the engine warms up, the thermostatic spring is warmed by air coming from the heat stove, which is a metal box close to one exhaust manifold. The spring relaxes and opens the choke all the way once the engine has reached operating temperature.

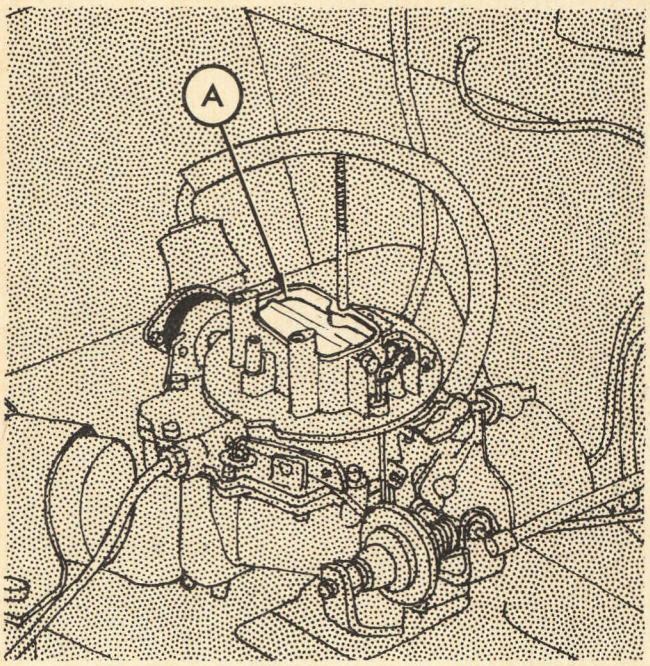
Generally, this is how the carburetor functions. Each automobile uses a different type of carburetor. It may have a combination of one, two, three or four barrels or bores and many extra parts, due to the requirements of fuel metering and emission controls. For more information, see Petersen's BASIC CARBURETION AND FUEL SYSTEMS or consult the shop manual for your particular car.

Because of the complexity of the carburetor and the fact that many of the adjustments are sealed to prevent upsetting the emission control system, most carburetor work is beyond the scope of this book. However, we have included a few simple checks to help you determine if your carburetor is in good working order.



1. To gain access to the carburetor, remove the air cleaner cover (A). This is the large metal cover on top of the carburetor. Usually the air cleaner is fastened by a single bolt or nut in the center. There may be several hoses or other connections to the air cleaner that must be removed. These are parts of the emission control system. Examine the filter element (B) in the air cleaner. If it is dirty or oily, it may be a cause of carburetor problems. Look carefully at the outside of the carburetor and check the linkage to see that it moves freely. Stains of gas or buildups of grease or dirt on the outside of the carburetor can indicate leaks in the gaskets. If the inside of the carburetor bores are extremely dirty, the carburetor is in need of disassembly and cleaning. Examine all lines, rubber and metal, that lead to the carburetor for cracks or crimps that may cause fuel flow problems to the carburetor.

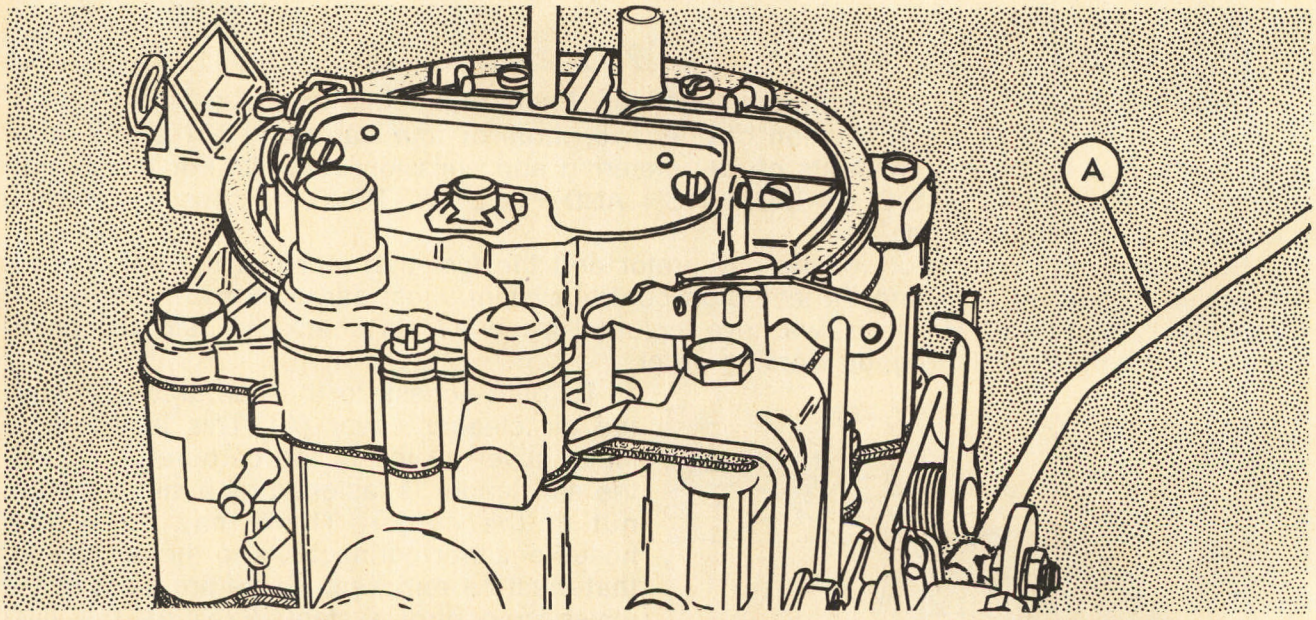
TROUBLESHOOTING THE FUEL SYSTEM



2. A quick check of choke operation may be made by checking the position of the choke plate (A) when the engine is off. The plate should be nearly closed.

NOTE: ON SOME CARS, THE CHOKE MAY BE IN A CENTER POSITION IN THE CARBURETOR WHEN THE ENGINE IS NOT RUNNING. DEPRESS THE GAS PEDAL FIRMLY TO THE FLOOR AND RELEASE IT. THE CHOKE PLATE SHOULD NOW BE NEARLY CLOSED. IF THE CHOKE DOES NOT MOVE FREELY, EXAMINE THE LINKAGE TO SEE IF IT IS BINDING. THE CHOKE LINKAGE IS ADJUSTABLE EITHER BY LOCK NUT OR BY BENDING. SEE YOUR SHOP MANUAL FOR INFORMATION ON ADJUSTMENT.

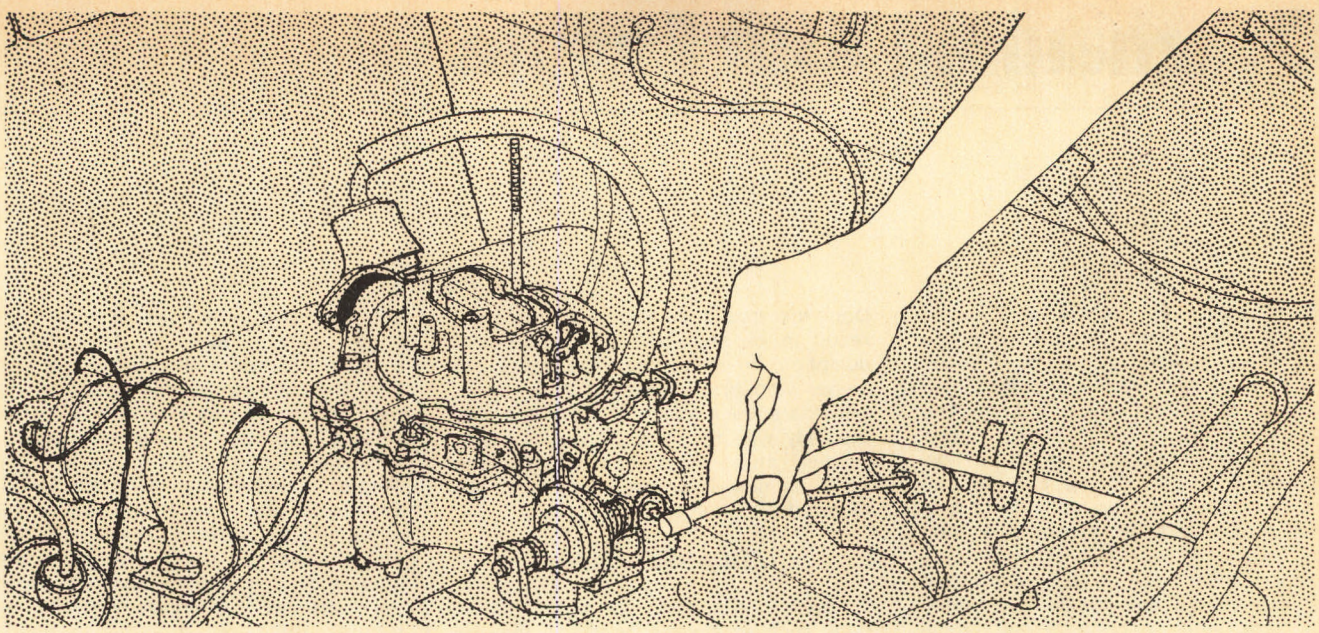
With the choke closed, start the engine and let it warm up to normal operating temperature. As the engine warms, the choke should slowly open to allow more air to enter the engine.



WARNING: THE ENGINE SHOULD BE TURNED OFF WHEN YOU CHECK THE ACCELERATOR PUMP TO PREVENT POSSIBLE ACCIDENT OR INJURY FROM ENGINE FIRE.

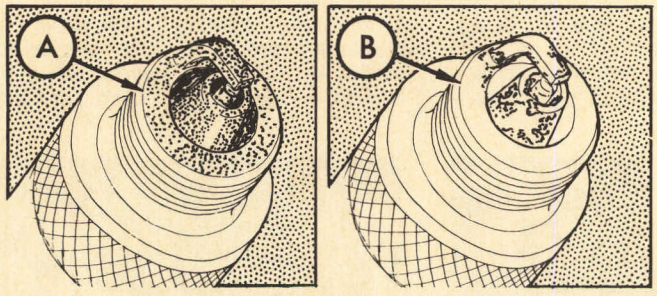
3. The action of the accelerator pump may be checked by grasping the throttle linkage (A) and operating it quickly while looking into the carburetor. If a spray of gas can be seen when the linkage is pulled, the accelerator pump is working.

NOTE: IF NO GAS IS OBSERVED SQUIRTING INTO THE BORE, THE TROUBLE COULD ALSO BE THAT THERE IS NO GAS IN THE FLOAT BOWL. CHECK THE FUEL PUMP AND FUEL LINES TO SEE IF GAS IS REACHING THE CARBURETOR.



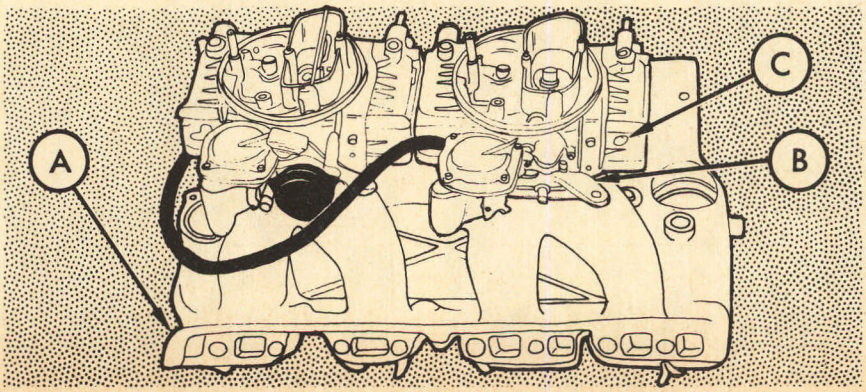
4. Checking the air/fuel ratio of the carburetor requires a specialized piece of test equipment called an exhaust gas analyzer (see Petersen's AUTOMOTIVE TUNE-UP AND TEST EQUIPMENT). However, the following simple check can give you a good idea of whether your carburetor is performing correctly and if it needs adjustment or overhaul.

Remove the air cleaner to expose the top of the carburetor. Put the transmission in neutral and set the emergency brake. Start the engine and let it warm up to operating temperature. In one hand, grasp the throttle linkage and pull until the engine speed comes up to about what it would be at a road speed of 30 mph (this does not have to be exact). Place your other hand or a piece of stiff cardboard over the carburetor and slowly lower it to close off part of the carburetor's flow of air. If the engine slows down very slightly, the carburetor is properly adjusted. If the engine speeds up slightly, it is too lean (not enough fuel). If it doesn't speed up at all, the mixture is too rich (too much fuel). Either of the second two conditions indicates that the carburetor needs adjustment or work. See your shop manual or your local mechanic.



5. Spark plugs can also be an indicator of air/fuel ratio. This ratio should be roughly 12.5:1 to 14.5:1 (air to fuel). Spark plugs that are white or show evidence of burning (A), indicate a lean condition. Plugs that are covered with a soft, black, sooty deposit of imperfectly burned fuel show a too rich condition (B).

NOTE: THESE SPARK PLUG READINGS CAN ALSO BE CAUSED BY OTHER PROBLEMS. REFER TO THE CHAPTER ON IGNITION SYSTEMS.



6. A persistent lean reading accompanied by low power may indicate a vacuum leak at the base of the carburetor (B) or around the intake manifold on top of the engine (A). Leaking vacuum lines, clogged vents for the float bowl (C) and the wrong internal metering parts in the carburetor can also cause the car to run lean.

Overhauling Your Engine

Many young people who would like to work on cars feel that a carburetor, distributor, or even a light switch is much too complicated for them to attempt taking it apart. The engine block is something else. Everybody seems to feel that no matter how little he knows about the car, he can unscrew nuts and bolts with the best of them. Many budding mechanics get their first taste of wrench twisting when they take a cylinder head or an oil pan off an old engine. It's unfortunate that young men who want to become mechanics should consider engine work as being easy or something that they can do without having to study up on. In reality, engine work cannot be done well by someone whose only qualification is grease under his fingernails and a lot of nicks and cuts on his hands.

Overhauling an engine is not simply a matter of taking it apart and throwing it back together. A man who rebuilds engines can truthfully be called an automotive machinist. He has to be able to work accurately to tolerances of less than 1000th of an inch. It is true that he does not have to have as delicate a touch as someone who works on carburetors or distributors, but his sensitivity with a micrometer is the equal of anybody who sets the gap on a pair of distributor points to the exact thickness of a feeler gauge.

An engine overhaul done correctly will result in the same amount of life that was obtained from the original engine. Done incorrectly, an engine overhaul will result in burned valves, high oil consumption, knocking bearings, and a car owner who firmly believes that engine rebuilders are a bunch of clods and that the only way to go is with a new car. Actually, an engine can be rebuilt just as good as new if proper techniques are followed.

DISASSEMBLY

Repair of a specific portion of the engine, such as a valve or piston, may be performed in most cases with the engine still in the chassis; but an extensive overhaul necessitates that the engine be removed from the car. This is one place the amateur can create many problems for himself. All the engine wiring must be disconnected, exhaust pipe and fuel line must be removed, throttle linkage detached, and the radiator hoses loosened.

Unless the mechanic has worked on a specific car several times, he usually finds it helpful to tag each electrical wire with a piece of masking tape, making note on the tag exactly where the wire connects (generator field, coil, oil pressure, etc.). The fuel line is taken loose at the fuel pump and plugged (otherwise the gas may siphon out and create a fire hazard), then the line is tucked out of the way. The exhaust headpipe(s) is often difficult to remove due to rusted nuts. A generous application of rust penetrant will cure this problem quickly.

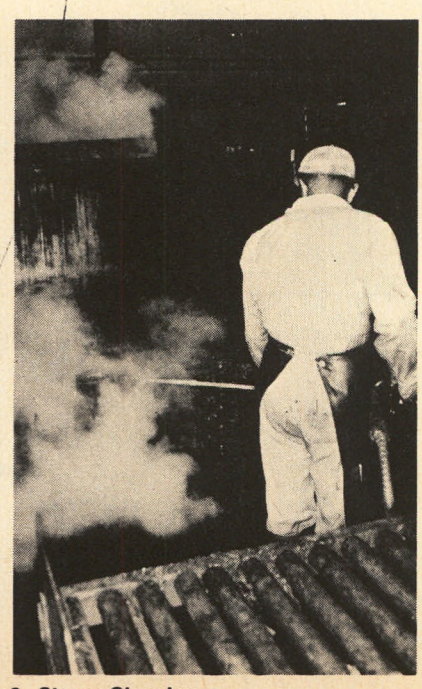
Before the bolts holding transmission and engine together are removed, the engine weight must be supported by either a hoist or a jack beneath the oil pan. The front motor mounts can usually be loosened at any time. While all the various accessories can be removed while the engine is still in the car, it is simpler to leave them in place for the time being. However, always remove the carburetor before lifting the engine from the chassis, or you'll stand a good chance of breaking the alloy casting. If the hoist chain is adjacent to the distributor, the latter should also be removed.

An engine stand is one of those luxury items never essential but always helpful to mechanics. Quite often a spare stand can be borrowed from a friend, and stand fabrication kits are available through parts supply houses. As an alternative, some kind of portable engine dolly will suffice. Never work on an engine on a dirt surface! Always have a clean floor and keep any dust to an absolute minimum.

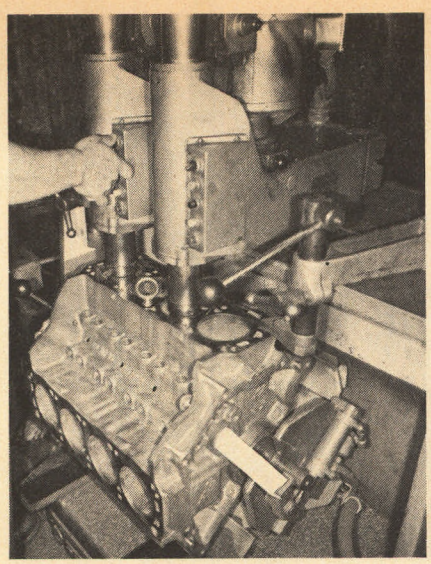
Once the entire engine package is removed from the vehicle, direct disassembly may begin. At this time it must be pointed out that whatever comes off the engine first will usually be the last for reassembly. That is, the exhaust manifolds-heads, etc., come off first and go on last.

Unless he is careful, the mechanic can misplace a simple, but vital, bolt or nut or bracket. Jars and boxes should be labeled and parts from each particular

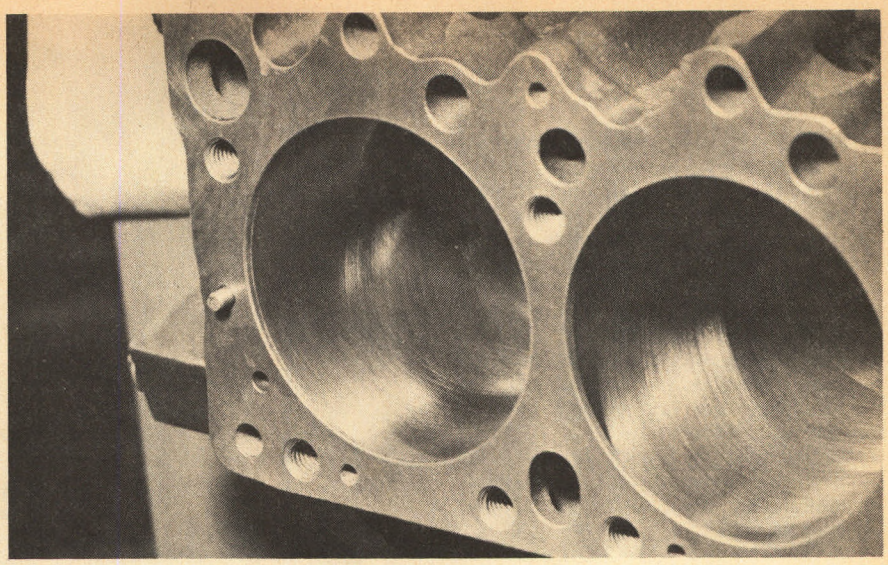
1. Awaiting Rebuilding



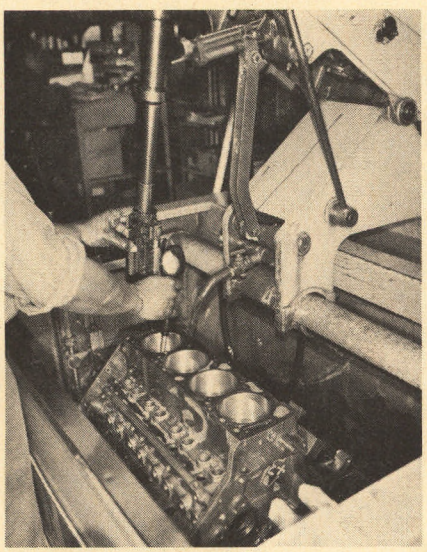
2. Steam Cleaning



3. Boring the Cylinder Block



4. Crosshatch Patterns



5. Honing the Cylinders

1. Engines—engines—engines—all awaiting rebuilding at Tomadur Engine Company in California's City of Industry. The only factory-authorized Ford rebuilder on the West Coast and the only factory-authorized Chevrolet rebuilder in the U.S., Tomadur rebuilds up to 1500 monthly and maintains ground vehicles of all major airlines at the L.A. airport.

2. We're going to follow a Ford 390-cu.-in. block through Tomadur's rebuilding procedure to give you an idea of how a professional rebuilder does it. A thorough steam cleaning follows disassembly to the bare block.

3. All cylinders are rebored two at a time using this Rottler Boring Bar. Once machine is set to specs for the type of engine on the line, the rest is automatic.

4. This is the proper crosshatch pattern in a cylinder bore. If angle is too shallow, rings will not seat during early stages; oil consumption and compression will also be poor.

5. After reboring, cylinders are finish honed. This produces the desired 45° crosshatch pattern on each cylinder wall, insuring maximum ring life and minimum oil consumption.

area placed in separate containers; *i.e.*, generator and bracket, head bolts, etc.

It is absolutely essential that the amateur carefully study each piece during disassembly. Note the sizes and number of bolts involved, the position of the piece, and any other peculiarity. Blindly tearing an engine apart is a good way to a future basket case that will have to be turned over to an unhappy professional.

As each major component, or group of parts, is taken from the engine, those caked with grease or oil should be set in a bucket of solvent and cleaned. Always work with a group of parts, such as connecting rods and pistons, to avoid misplaced pieces. The order of disassembly is not terribly important, but as a matter of convenience, the heads are usually removed first. What is found beneath the valve covers will be a direct indication of engine condition—thick sludge is normally a sure sign of a heavily worn engine.

The intake manifold must be removed, followed by the valley cover. Next all head bolts may be removed and, in the case of an overhead valve engine, the rocker arm shaft assembly taken off as a unit. Heads on any engine are usually quite heavy, so remove with caution. OHV heads are no problem, but flathead engines often use studs rather than capscrews to position the heads. If this is the case, the head may seem firmly rooted in place. While there are special cutters that slip over the stud and simplify removal, the more common method is to gently tap around the head circumference with a mallet. Once the head is loosened slightly, screwdrivers may be inserted at each end; then pry lightly and tap until the head is off. Obviously, once is enough with this problem, so the studs may be replaced with capscrews if desired. Set the heads aside and continue with the engine disassembly.

In the absence of a good engine stand, the engine may be set vertically on the bellhousing and the water pump/timing chain housing removed. The oil pan follows, with the oil residue at the pan sump bottom telling more of the engine condition story. Any kind of bearing or excessive metallic wear will be apparent as a thick or thin coating on the sump floor. Sludge buildup on the oil pump pickup screen will be common if the engine has not been cared for, and will mean excessive wear at all lubricated surfaces. Remove the oil pump and set aside. Do not disassemble the major components at this time. It is easier to take them apart when ready to work on them, and this cuts down on the small pieces lying about the work area.

Use a center punch or number stamp to mark the connecting rod caps, then remove them. Very gently tap the loosened piston assembly out the top of the cylinder. Use the handle of a hammer for this job, not an object likely to damage the rod bolt threads or the crankshaft bearing surface. It is especially critical to be careful of the crank journals. The rod bolts can scratch a journal easily, and the condition of a journal may not require repair unless it is damaged in disassembly. Before the piston assembly is removed, however, it is necessary to check the top of the cylinder bore for an excessive ridge. Run the fingernail up the shiny part of the bore. If the dull, discolored ridge at the top of the bore is more than a few thousandths smaller than the bore, the fingernail will hang up solidly on the ledge. In this case, the lip may have to be removed with a ridge reamer before the pistons are knocked out of the block. Otherwise it is possible to break the rings, and while new replacement rings are probable, the piston (which might be reusable) may be severely damaged by the broken ring and have to be discarded.

One of the greatest mistakes the mechanic can make is to reassemble the engine with mismatched connecting rods and rod caps. To preclude this, most engines have the rods marked on one side near the bolt to match the caps. There might be a number, or dots, or lines. In the event there are no matching ID's, make your own before removing the assembly. After the rods are removed, replace the cap in the proper manner.

The main bearing caps are held in place by large-diameter bolts which usually need a little extra effort to be broken loose. In addition, some engine designs have the main caps recessed slightly in the block web to ensure maximum strength. A slight tap will unseat these

caps. The crankshaft is then free for removal.

While it's best to replace camshaft bearings, they may be retained as an absolute budget measure. Although this is not recommended, the bearings can escape injury during disassembly if the camshaft is very, very carefully removed through the front of the block. However, before a camshaft may be removed each valve lifter must be taken out, and the location of each lifter should be carefully observed. Oversize lifters, especially hydraulic types, are not uncommon and may have been used.

With all the major parts groups thus removed, the engine is ready for careful inspection, cleaning, repair and finally reassembly.

CLEANING

While it may seem extra work, no part can be thoroughly inspected while dirty or oily. Obvious broken parts don't require cleaning to verify the need for discarding, but failures are generally small and hard to see. The initial cleansing may be nothing more than wiping an oily part dry, but it is important.

There are a number of different cleaning compounds, but under no circumstances should a highly volatile fluid be used, such as gasoline or benzene. Kerosene or a commercial cleaning compound available at the parts store is the best, and inexpensive. Stiff bristle brushes from the dime store are usually sufficient for most cleaning needs, while small-diameter, round steel brushes (such as used for cleaning gun barrels) are a necessity.

Initial cleaning may be limited to a group of parts. That is, the connecting rod and piston may be cleaned while still assembled, as may the head, distributor, etc. This is merely the first phase of cleanup. Although a thorough cleaning of the cylinder block may be deferred for a while, the crankshaft must receive an intensive cleaning at this time. Using the small round wire brush, clean the oil passages in the crank, and use the solvent liberally.

While most mechanics agree that "boiling out" the block and cylinder heads is a good initial cleaning process, many racing engine builders prefer to merely steam clean the block. Their reasoning is that the chemicals used for the hot boiling bath tend to enter the iron casting pores and remain there until the engine is again heated during actual operation. Then the compounds enter the oil. This is minor concern for a general overhaul, however, and is mentioned merely to point out that steam cleaning can be effective.

This is the initial cleanup only, and will be followed by a more comprehensive cleaning before the engine is finally reassembled.

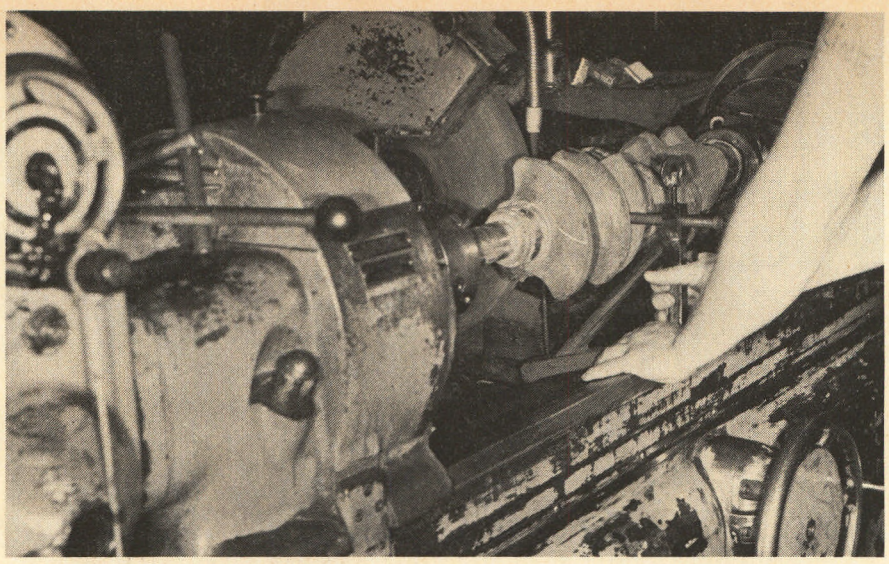
INSPECTING THE PARTS

It is not difficult to recognize an unusually worn engine part, particularly those parts generally accustomed to failure, such as bearings, rings, and valves. Obviously, a broken connecting rod will be easy to spot. Virtually impossible to see, however, is the rod almost ready to break. Continual work loads imposed upon any mechanical assembly will eventually lead to a failure of some degree. Finding that potential failure early is the key to successful engine rebuilding, and it's the main reason professional mechanics subject suspected bad parts and vital components to Magnaflux inspection.

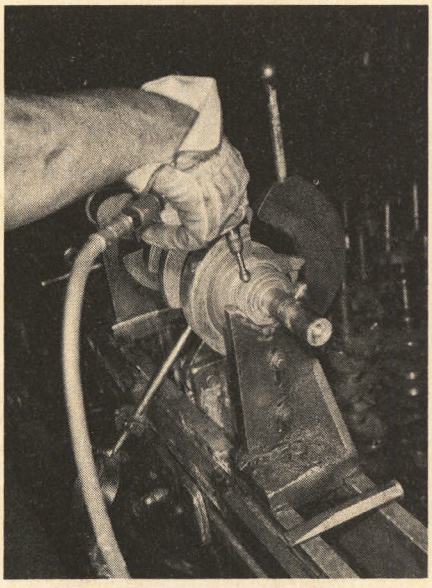
This type of inspection has become widespread during the past decade and is now available to the smallest communities, through either the auto parts stores or the heavy-duty/farming equipment dealers. Any engine rebuild should include a Magnaflux of the crankshaft, connecting rods and rod caps, connecting rod bolts and main bearing bolts. If the engine has been run for a long time, it is also wise to include the rocker arms and rocker arm shafts. Often such an inspection will reveal the smallest trace of a fatigue crack starting at some critical point, such as the radius of a crankshaft rod journal. If caught soon enough, such a potential danger spot can be repaired inexpensively by a machine shop. If a connecting rod bolt is ready to break, but appears normal to the eye, the rebuild is likely to be short-lived!

Anyplace there is metal-to-metal contact, suspect wear. This is the job of lubrication, surely, but wear is bound to occur to some degree in any mechanical apparatus. Look at the oil pump as a prime example. Here is a unit continually soaked in oil, but the pump end plate will wear nevertheless, due to the constant contact of the pump gears. Slight wear of any such area will appear as a polished surface. If the surface has not been receiving enough lubrication, the area will turn blue from excessive heat. Grooves worn in the surface are an immediate indication that the part should be replaced. As a general guide, replace a worn part if there is the slightest doubt of condition. Take that oil pump end plate, for instance. It could be resurfaced, of course, but the cost of this repair would be more than a new part.

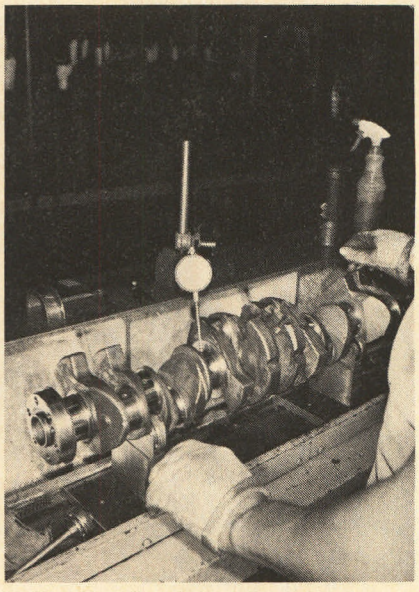
Just looking at a part may or may not disclose wear. A crankshaft journal should be shiny all the time, and unless there is discoloration due to overheat or gouges worn in the surface, the journal



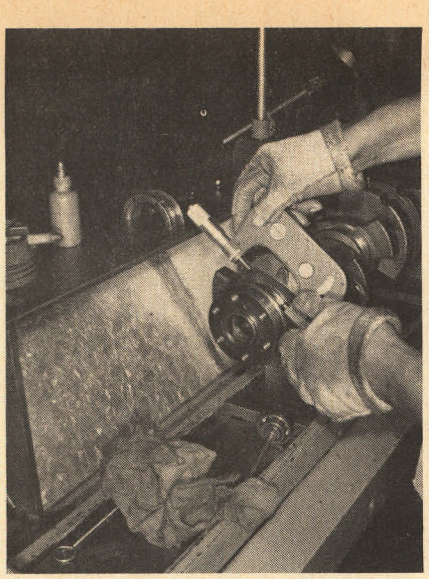
1. Grinding a Crankshaft



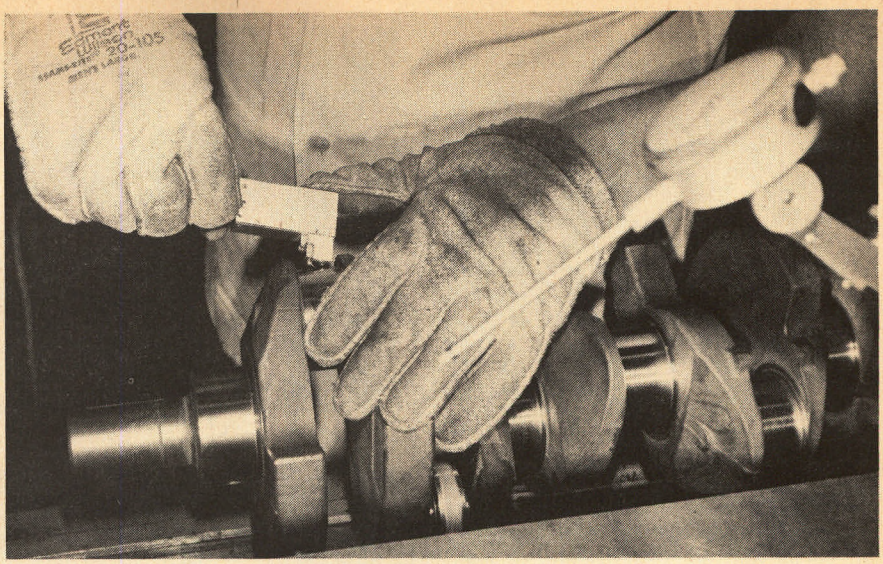
2. Chamfered Oil Holes



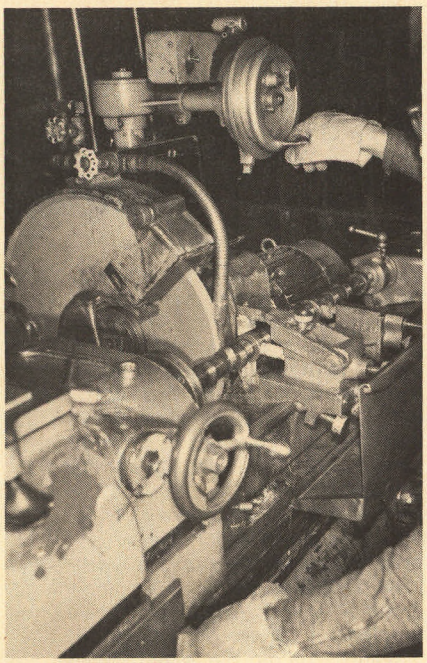
3. Checking Crankshaft Straightness



4. Miking a Crank Journal



5. Checking Journal Surface Finish



6. Grinding Camshaft

1. While the block is in the works, another line works on the crankshaft. After being checked for straightness, the crank is reground, and the journals are polished for the correct surface finish and clearance.

2. After a shaft has been ground, the edges of the oil holes are beveled to prevent shaving the bearing while the engine undergoes the break-in period.

3. Quality control inspector then checks crank with dial indicator to make sure that it's straight.

4. He also checks the size of the crank journals with a micrometer.

5. A magnetic pickup unit is connected to the measuring gauge and tells inspector if journal smoothness is correct. Too smooth a surface is as bad as one too coarse, as it passes oil too quickly.

6. While crankshafts are prepared, similar treatment is given to camshaft. Lobes must be perfectly shaped if engine is to run correctly.

may appear perfectly normal. The mechanic then relies on measuring instruments to detect undue wear.

There are three basic types of measuring tools a mechanic will use: the inside and outside micrometer, the feeler (thickness) gauge, and the dial indicator. The last is not an absolute necessity for the casual mechanic, but the first two are and should be used whenever necessary.

A micrometer, or "mike," is designed for linear measurement with accuracy of .001-in. or better. This means it will detect a measurement well within the range that concerns most mechanics. The inside mike is used for measuring the distance between two paralle! surfaces, and is commonly used to measure the cylinder bore (taper, size, etc.), connecting rod big end, and block main bearing bore. The outside mike is used to measure the outside diameter of cylindrical forms and material thickness.

When using an outside mike, always measure several different points on the cylindrical object. For instance, a crankshaft journal may be flat in one spot only, and sloppy mike use would not show that spot. Even if the person could not read the mike, he could use it as a comparison instrument and rapidly find a problem area.

The inside micrometer is a bit harder to use, because the instrument must be absolutely perpendicular to the surfaces measured. As can be seen, if the outside diameter of a crankshaft rod journal is measured, and a similar measurement taken of the inside diameter of a coupled connecting rod big end, the difference in measurements should be the exact clearance involved (taking into account the bearing thickness, if the bearing is not included).

A measuring device of sorts is Plastigage, a soft thread-like pliable material. Plastigage comes in specified diameters, and when flattened out to predetermined widths will equal some specified clearance. Common use of this material is to check clearance between crankshaft and main/rod bearings. A short length of material is laid crossways in the bearing, then the main/rod caps torqued to the correct reading. The crankshaft must not be rotated. The caps are then removed and the flattened piece of material measured to determine clearance.

Feeler gauges are an absolute necessity in any mechanic's toolbox, and may range through a variety of sizes and shapes. For engine overhaul, the feeler gauge will come into play often, measuring piston ring end clearance, valve lash, ignition point spacing, spark plug gap, rod side-play, crankshaft thrust play, and other critical clearances.

REPAIRING CRACKS AND THREADS

Although the amateur will find repairing cracks in the cylinder block or heads a touchy subject, he can do much for total block and head preparation without calling on a professional service.

The first thing to check for is warpage of the head(s) or block. Because cylinder blocks are relatively strong structures to begin with, any warping will usually be minimal in the case of cast iron. Alloy blocks (aluminum) will and do distort considerably, so they must be checked especially well. The critical areas of block warpage are head and crankshaft mating surfaces. The former may be corrected by grinding or milling if it is not too severe (seldom), and the crankshaft bore can be line-bored (common). The head(s) can be milled or ground true, but only if distortion is minimal (check with the machine shop for this minimum measurement; it varies with engine and operating condition).

To check for distortion, lay a perfectly straight edge of some sort across the surface and then try to slide a feeler gauge between the surfaces. Do this lengthwise, crosswise, and diagonally. As a guide, anything more than .020-in. is excessive warpage and requires machine shop correction.

Although corrosion is not a crack, it can cause irreparable damage, and must be expected if the engine is very old or of alloy construction. This problem will exist principally in the water circulation passages, and will be pronounced around the mating surface openings, as between head and block or water pump and block. If dissimilar metals are used

on the engine—such as an alloy block with steel cylinder liners, or alloy heads, or alloy water pump housing—an electrolytic action can occur. Clean the affected area thoroughly, grinding away any pieces that could become dislodged and work into the water system, and definitely determine if the sealing surface has been adversely affected. To counteract corrosion, always use a soluble oil or antifreeze mixed with the coolant.

A cracked cylinder block will show up right away if it is external, and may be welded by an expert professional. Under no circumstance should the amateur try crack repairs without qualified instruction. However, repairs are common when new replacement parts are difficult to find or expensive, such as in the case of an antique engine. External cracks are usually the result of water freezing in the block. The problem cracks are those occurring inside the engine.

Overhead valve engines are not prone to having cracked cylinder blocks (internal), but flathead (valve in block) engines are. This problem usually occurs between the valve seat and the cylinder bore, aggravated by poor water circulation and engine overheat.

Cracks between valve ports can be repaired by peening the fracture carefully (small cracks), or by welding. Large cracks that extend well into the cylinder bore make the block unusable.

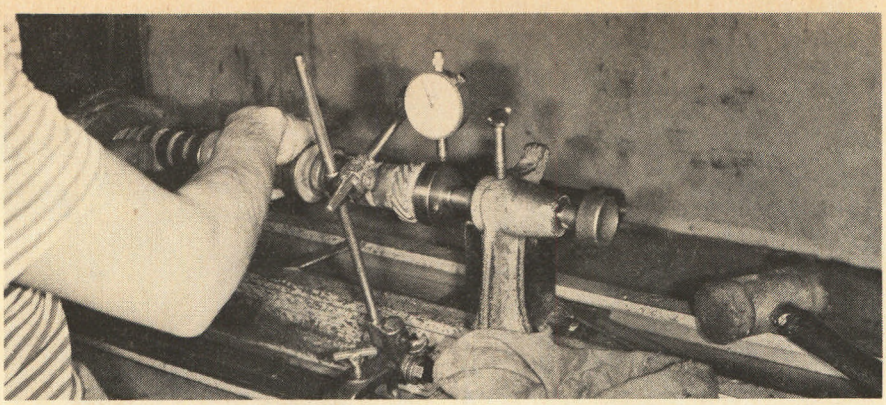
Sometimes cracks in blocks or heads are repaired by drilling holes at either end of the crack and inserting threaded studs. These are cut off at the surface and another hole drilled adjacent to the first, half in the cracked surface and half in the stud insert. This is continued until the crack is filled. But as can be seen, crack repair of any kind is tedious and time consuming, and necessarily, expensive. Replacement of the part is usually less expensive.

Threaded holes in the block and head(s) can easily become damaged, especially on older engines. The solution is to run the proper size tap into all threaded holes, cleaning away rust and refuse metal or dirt in the process. If the threads have been damaged beyond return to normal size, the simplest method of repair is to drill the hole oversize and use a thread insert, such as Heli-Coil. Use of such thread inserts is especially advisable in alloy blocks or heads.

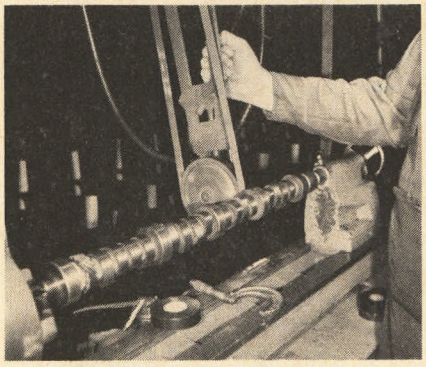
Slight distortion is a standard part of fastening two metal surfaces, and is engineered into both the bolt and the pieces being bolted together. However, in the case of threaded holes in the block or head, this distortion may often be too much, and will cause the threads to "slip." The resulting lip around the threaded hole will then make subsequent mating less than ideal. The cure is to countersink each threaded hole very slightly.

REPAIRING THE CYLINDER BLOCK

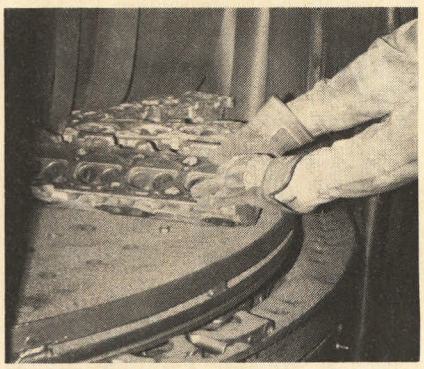
Wear in an engine is usually greatest in the cylinder bore, followed by the crankshaft bearing areas, the valve guides, valve seats, etc. Thus, much attention to basic cylinder block reconditioning is necessary in practically any engine overhaul.



1. Checking Camshaft



2. Polishing Camshaft



3. Sandblasting Cylinder Heads

During disassembly the ridge at the top of the cylinders was removed. This was, in itself, a definite indication of cylinder bore wear. However, a cylinder will not wear the same at top and bottom; rather, the top will wear more than the bottom. The result is a taper to the bore, and this is the culprit that causes most overbore requirements. When bore taper, or the difference in size between top and bottom, exceeds .010- .012-in., the block needs boring. A very slight taper can be cleaned up by a hone, as can minor scratches on the cylinder wall, but such easily corrected conditions are unlikely to exist in any engine with 50,000 or more miles.

While pistons may sometimes be resized if the cylinders are only slightly enlarged by honing, the typical rebuild will require a reasonable overbore and new oversize pistons. These pistons should always be bought before the block is bored, then the block matched to the pistons. Sometimes, the piston manufacturer will include the operating clearance in the piston size, sometimes not, so make sure what size you're working with and you won't experience trouble.

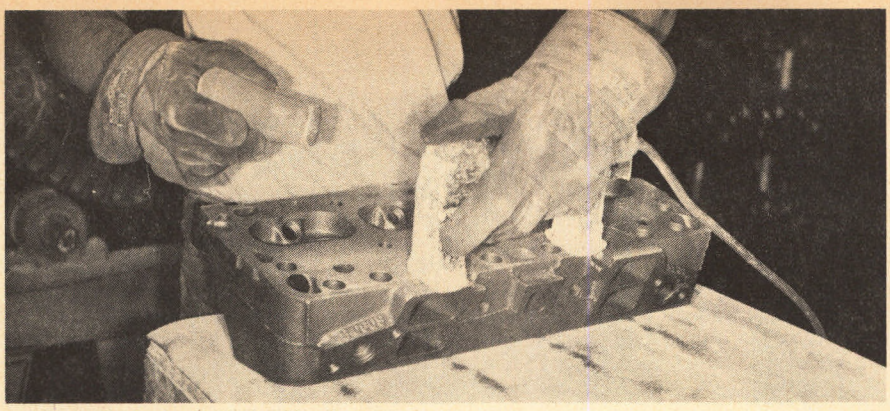
Because most older engines are not nearly as powerful as their modern counterparts, increasing the displacement via an impressive overbore is a direct route to greater power. However, this is possible only on engines made before the thinwall casting process came into widespread use in the late 1950's: a process designed to reduce engine block weight drastically. Therefore, older engines can usually take up to .125-in. overbore, while thinwall engines can seldom take more than .030-in. In essence, this means that the modern engine can seldom take more than one rebuild where boring is required.

If the piston pin has slipped in the piston, it can cause extensive damage to a cylinder wall, sometimes beyond repair with an overbore. In such a case, the cylinder can be bored to accept a sleeve, but the cost is high. If the cylinder has been scored due to broken rings or seizing pistons, an overbore will probably also be necessary. However, if aluminum pistons have only deposited excess alloy material on the cylinder wall, a minor honing will usually solve the problem.

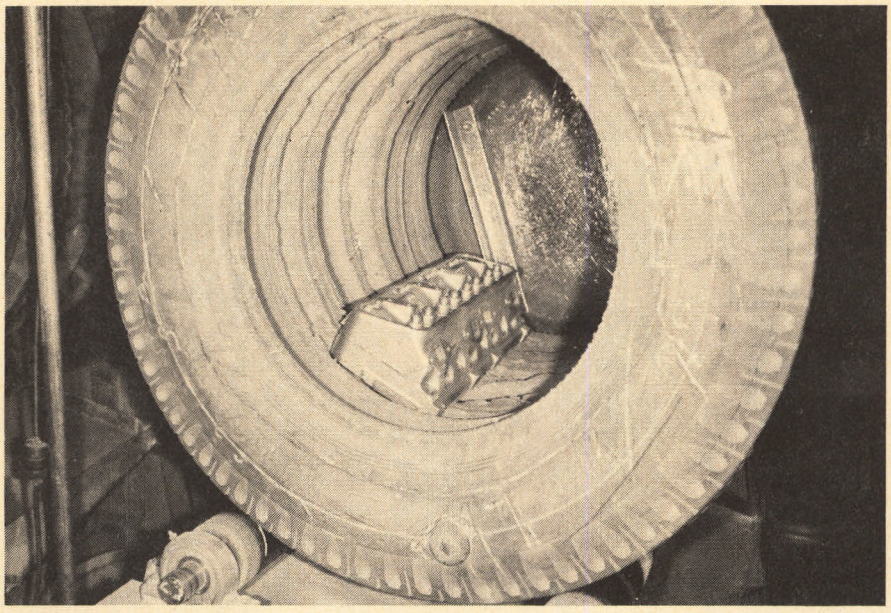
Using a boring bar is not difficult, but such equipment is not likely to be in the amateur's toolbox. Instead, work such as this is best farmed out to a machine shop specializing in such things, and will cost from $2 to $4 per cylinder. Nevertheless, it behooves the mechanic to understand how the boring bar is used.

Boring bars may locate off either the head surface or the crankshaft bore, but in each case the idea is to get a bore exactly perpendicular to the crankshaft centerline. Therefore, the block must be securely mounted to the cutting equipment. Seldom is the entire cut made at one time, rather the bar may need a few passes through the hole to get the preliminary sizing. Most bars are automatic, in that they will shut off when a predetermined depth has been reached, but all must be attached to the block carefully to insure accurate boring for each cylinder.

Following the boring operation, each cylinder must be carefully honed, a procedure usually included to give the final sizing. The correct surface for a cylinder wall is not glass-smooth. New rings will not seat when the walls are perfectly smooth, and oil control or com-



4. Magnafluxing a Cylinder Head



5. Cleaning a Cylinder Head

1. After grinding, camshaft is also inspected for correct dimensions before polishing of journal surfaces.

2. After journals are given the final polishing, all exposed camshaft surfaces will be wrapped with tape to prevent damage while awaiting installation.

3. Heads are sandblasted as first step in their rebuild. A circular stage carries heads through process and returns them to operator.

4. Each head is then magnafluxed before further work is carried out. Rejection rate here can run as high as one out of four.

5. After head is checked for cracks, it's placed inside these constantly revolving tires and tumbled to free whatever sandblasting debris might remain in the passages, then it's completely cleaned with compressed air.

pression blow-by is sure to be a problem. At the same time, a too smooth cylinder may score from lack of lubrication.

While the honing operation is usually included with any bore job, the mechanic may sometimes be required to do the job himself. In this case, he must remember that the scratches are so tiny they can be measured only in microinches (that's one millionth of an inch!). However, he will force the revolving hone down the cylinder at a smooth pace, then pull it back up so a cross-hatch pattern is formed on the cylinder walls. This cross-hatch will have intersecting lines from 45° to 60°.

The amount of clearance involved in piston-to-cylinder wall fit will vary considerably due to engine operation. However, since most modern replacement pistons take into account the wide operational requirements of automotive engines, it can be assumed that .001-in. per inch of piston diameter is a safe guide. This means a 4-in. piston will get .0035 to .004-in. wall clearance. In all cases, the piston manufacturer will have a recommended clearance and this should be followed explicitly. It may be as little as .0005. Of course, engines that will be operated at rpm's greater than stock, such as racing engines, will require greater piston clearances.

After the cylinder walls have been honed, each piston should be slipped into a cylinder and the clearance checked with a long feeler gauge.

Following the reboring job, the top lip of the bores may be slightly chamfered to make it easier to get the rings into the bore. The block is line-bored if necessary. Again, this is a job normally left to a machine shop, because they have the equipment. What is involved is a safety check of the crankshaft bore, since it can get out of alignment due to distortion. For line-boring, the main bearing caps are torqued in place, then the bore is trued. The camshaft bore may also be line-bored, but this is not common.

The lifter bores should always be checked, and if the clearance is greater than .005-in., new lifters will be required (oversize). In this instance, the lifter bores are also honed out.

After all the block machine work has been accomplished, the soft plugs (freeze plugs) should be removed and replaced with new ones. These plugs often corrode on the inside, and although they look OK, may soon fail.

The final block cleaning is now at hand. The block can be given the hot or cold tank cleaning treatment (soaked), or it can again be steam cleaned. In either case, after this cleaning, the newly machined surfaces should be thoroughly washed with ordinary soap and warm water. All oil passages in the block should be cleaned out with the small wire brush, and blown clear with compressed air. This operation is vital, since any small particles of metal or dirt trapped in an oil gallery can cause immediate engine failure. After this cleaning, all machined surfaces should be coated with a light oil to inhibit rusting.

The engine may be painted with some kind of heat-resistant paint, preferably that from a spray can rather than by brush, as a thick coat of paint will tend to flake off later on. All the inside surfaces of the block that are not machined may be painted with a very light coat of Rust-Oleum. This will tend to keep sludge from finding a foothold on the rough casting; the practice is common in race engine building. To keep dust from collecting on the oiled block, cover it with a plastic bag like those available from the dry cleaner.

THE CRANKSHAFT

A brand-new crankshaft is seldom necessary to an engine overhaul, unless a journal has been severely damaged. However, it is not common to grind a crankshaft more than .030-in. undersize.

Wear to a crankshaft may come from several different causes. Forces on a rotating crankshaft are much heavier at some points of the journal than at others. As an example, the explosion force is much stronger than the compression stroke force, which will tend to cause a "flat spot" on the journal at that point. A bent or misaligned connecting rod will rotate in a cocked fashion on the crankpin journal, and this will cause the bearing surface to wear in a taper. The engine block may twist during operation, and in the case of engines with only three or four main bearing journals, the crankshaft can distort during rotation. All this will tend to wear the main journals in either a tapered or warped fashion and regrinding is necessary.

Individual bearing journals will not have the same amount of wear, because of oil supply to specific journals, abrasives entering the oil, misaligned rods, etc. Therefore, some kind of crankshaft reconditioning should be expected with any overhaul.

Very carefully inspect the crankshaft journals, both main and connecting rod,

Overhauling Engine

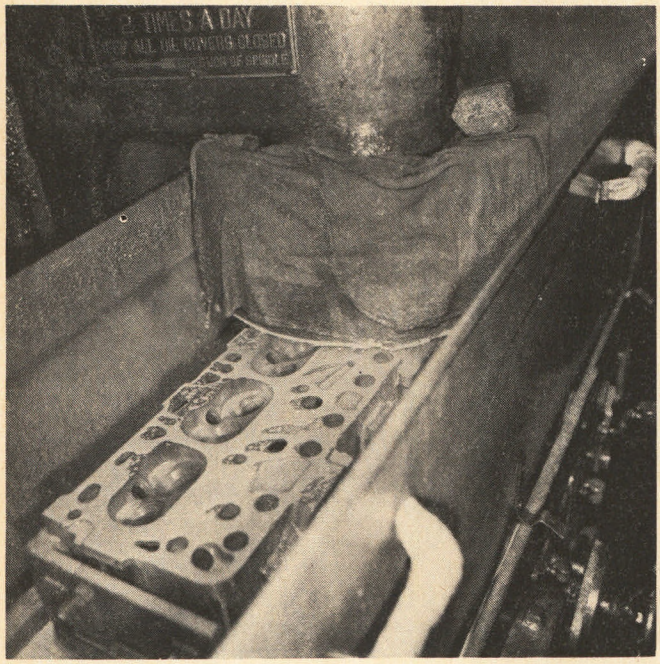
as tiny cracks may develop here long before a failure occurs. If these cracks are visible to the eye, replacement of the crankshaft is a necessity. At the same time, a Magnaflux inspection will reveal unseen cracks. Repair of a crankshaft may include regrinding the journals to an undersize, or welding and regrinding. If the journal must be repaired in any way, it is advisable to have the edges of each journal radiused slightly. A sharp junction between journal and check will encourage stress concentration and metal fracture.

To determine the condition of the crankshaft, measure with an outside micrometer, checking both sides of the journal. Two measurements should be taken at each point, 90° to each other (top and bottom, and sideways). Because of the operating pressures creating a flat spot on the top of the crank, this measurement will usually be slightly smaller than the sideways measurement, and is normal. However, if this reading shows a difference of more than .002-in., the crankshaft must be reconditioned.

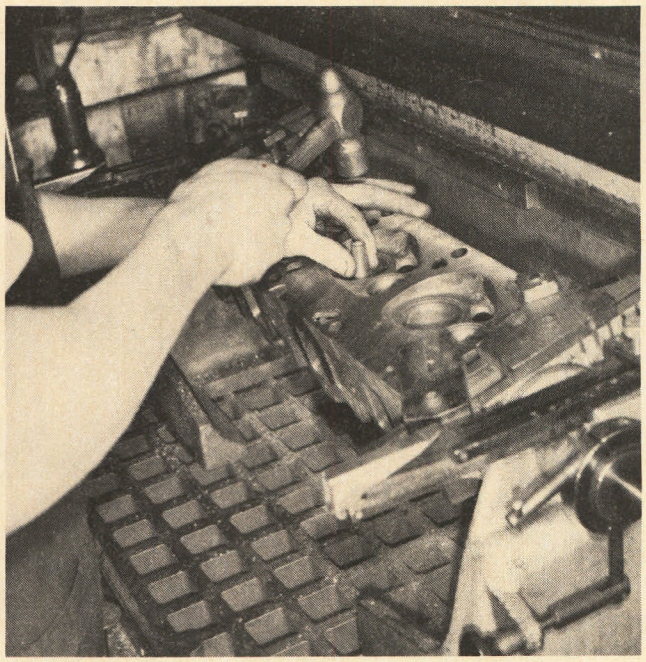
Bearings come in a number of undersizes (the bearing is really oversize, to compensate for the worn crankpin), from .001 on up to above .030-in. If the crankshaft is in good shape except for a minor undersize, a replacement bearing may be all that's necessary. If the shaft needs regrinding, it may be taken down .010, .020, or .030-in. When a shaft is reground, it is usually taken down to a standard undersize to make bearing selection easy.

It is not unusual for a crankshaft to be bent, that is, warped through the centerline. When a machine shop repairs a crankshaft, they always check for this warped condition by using a dial indicator along each main bearing journal. Only minor hydraulic pressure or taps with a sledge are required to straighten the shaft. Even if the shaft proves reusable without journal regrinding, it should be checked for straightness, anyway.

Never install a reconditioned crankshaft as received from the machine shop! It may not be clean. Anytime a crankshaft is removed from the engine, thoroughly clean each and every oil delivery gallery with a wire brush (preferably a stainless steel wire). Wash the crank with both clean solvent and warm soap and water, then blow it dry with compressed air. The tiniest bit of carbon or foreign material in the oil passages can lead to a sudden demise of an otherwise excellent engine.

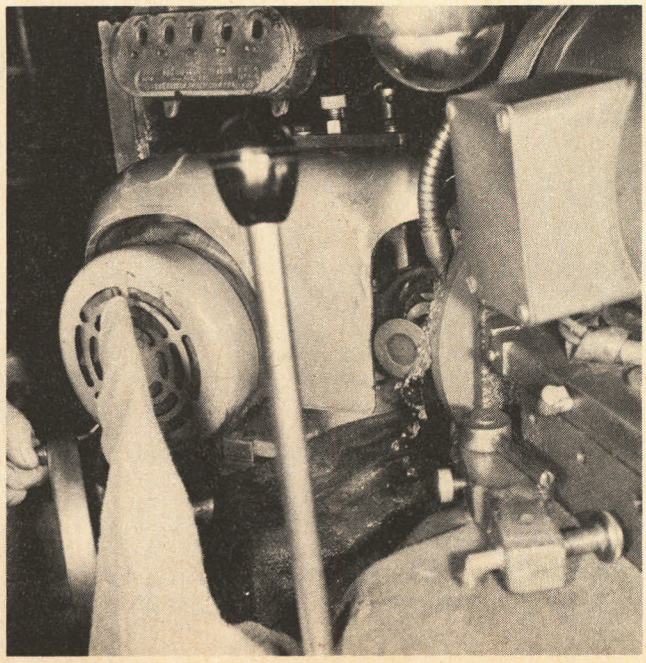


1. Resurfacing Cylinder Head



2. Installing New Valve Guides

3. Grinding Valve Seats



4. Facing Valves

1. Head is resurfaced where necessary to assure uniform fit when replaced on block. Automatic machine moves head back and forth under a steady stream of oil.

2. On heads that lack integral valve guides, old ones are machined out, replaced with new ones, and honed. This insures that valves will all work in a straight line.

3. Cutting a valve seat increases the width of the seat. Final stone used has a 60° angle to face seat and return it to correct width.

4. Each valve is then checked for straightness and refaced.

5. Valve spring assemblies are not complicated; note the little seal on the intake valve stem. It's there to keep oil from running down the valve stem and getting into the combustion chamber. If additional seals were used on ends of guides, they'd have to go inside the inner spring, but there might not be room for such seals on this double spring setup.

After the crankshaft is clean, coat the machined surfaces with a light oil and prepare to install it in the block.

BEARINGS

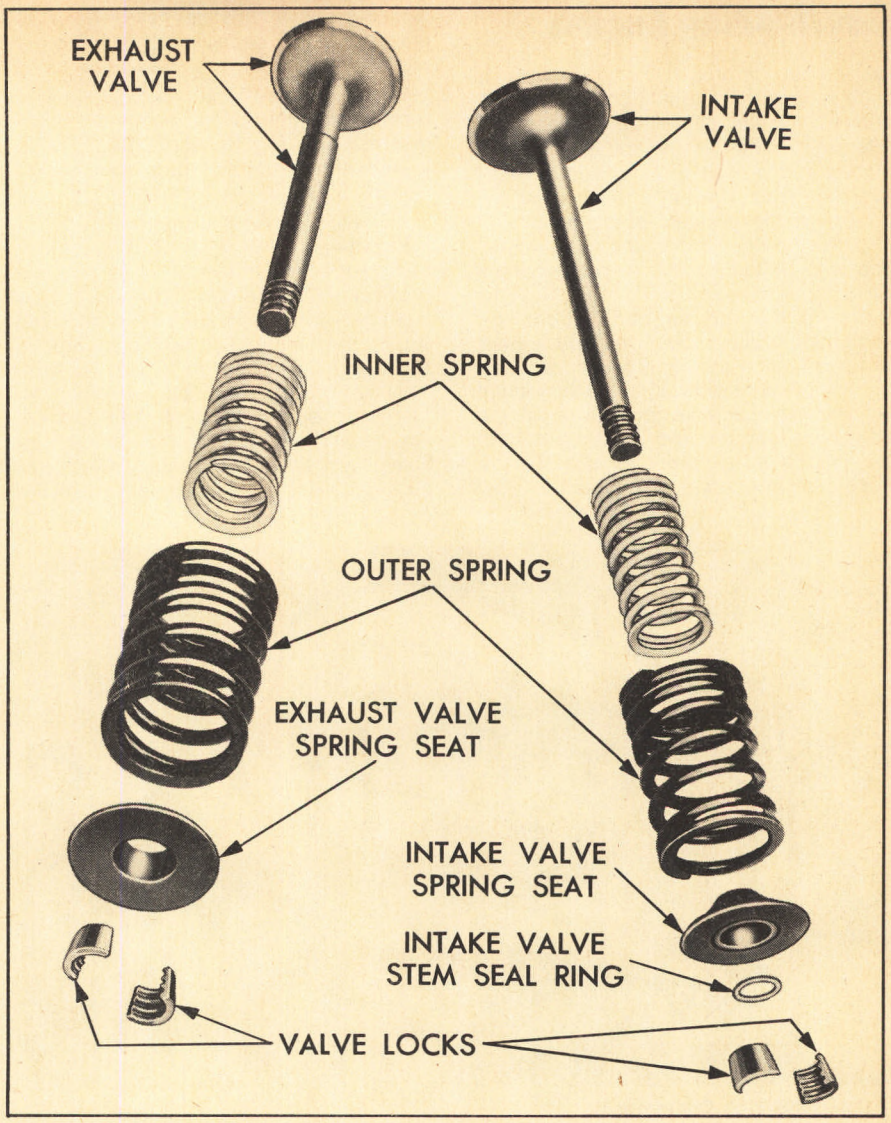
Rod and main bearings are the most abused parts of an internal combustion engine. They must operate under the most difficult conditions, yet remain faithful for thousands of miles. And even when they do fail, they are not expected to cause excessive damage to their closest ally, the crankshaft. Because of such high requirements, bearing designs and construction have received special attention for as long as automobiles have run.

There is no single bearing metal that can meet the requirements of an engine, at least in the pure state. Such a material would have to have a melting point consistent with manufacturing processes, the proper malleability (softness), low coefficient of friction, high fatigue resistance, resistance to high engine temperatures, resistance to corrosion, ability to adhere to steel or bronze backs (shells), and ready availability at reasonable cost. Since no specific material fits all these requirements, bearings are therefore made of alloys.

These alloys include tin-base babbitt, lead-base babbitt, copper, aluminum, and multi-layer copper and aluminum. Most bearings in use today are of the thin-shell type, which consists of a thin layer of bearing alloy supported by a steel backing. For heavy-duty service, such as racing engines encounter, the multi-layer bearing is more reliable.

Unless the engine is being rebuilt with heavy-duty operation in mind, it is best to follow the original manufacturer's recommendation as to bearing type. If the original bearing had a certain type of oil hole and no grooves, then the replacement bearing should be similar (unless otherwise specified). Under all circumstances, the oil hole in the bearing must align with the delivery hole in the block or connecting rod.

Most modern engines keep the bearing inserts in place by a locating lug stamped in the bearing shell and a corresponding slot in the housing to prevent rotation.



5. Valve Spring Assembly

Bearing manufacturers also make each bearing half slightly greater than 180° This allows a slight bit of bearing to stick up beyond the intended housing. When the other half of the bearing assembly is installed and torqued into place, this "crush" area will cause the bearing to positively seat in the housing. Never file the edges of a bearing because it seems too big, and make sure there is no foreign material between the mating edges of bearing halves. In either case, the proper crush would be disturbed.

CONNECTING RODS

Although the engine may have been running reasonably well before disassembly, with no apparent connecting rod trouble, each and every rod should nevertheless be checked and reconditioned if necessary. Such service is simple: recondition the big and little bores, and straighten if needed.

However, reconditioning of the rod is only a recent requirement, necessary because of the changes in both rod and bearing design. When engines were seldom producing more than 200 horsepower, and internal loads were much less than the modern engine, rods could—and would—seemingly last forever. While the primary function of the rod is to transmit combustion forces to the crankshaft, it has the secondary responsibility of lubricating other parts of the engine. The condition of the rod big end (saddle bore) must therefore be as near perfect as possible. If the rod bearing fit is improper, it can cause scored cylinder walls, pistons, and rings, or excessive oil pumping.

While insert bearings have undergone excellent design changes during recent years, connecting rod design has kept pace, with heavy-duty and high-performance requirements creating a full line of top-quality rods for practically any engine. If an engine is going to be subjected to greater than normal loads, better rods should be installed. As an example, a Chevrolet V-8 engine (283-cu.-in. small-block version) can have as much as 5 tons of explosive pressure exerted on the piston. In addition to this tremendous force, at 4500 rpm the rod reverses direction 150 times per second. That's hauling, and the rod is doing a tremendous job under strenuous conditions.

New rods are expensive, so rebuilt rods are commonly used. In this case,

the normal approach is to remove a slight amount of metal from the mating surfaces of the cap. This reduces the internal diameter of the rod, thus allowing the saddle bore to be honed to original size. This kind of rework must be done with the greatest possible accuracy, therefore it is a machine shop operation and should be left to professionals with proper tools.

Should the rod be bent, it can be straightened in a press. If the rod is bent edgewise, such as might occur from seizure, or if bent sideways, the alignment will be improper and cause wear at the bearing. After the rod is straightened, the rod center-to-center length must be accurately measured, and the rod may be checked against a flat surface to make sure all bends or twists are removed.

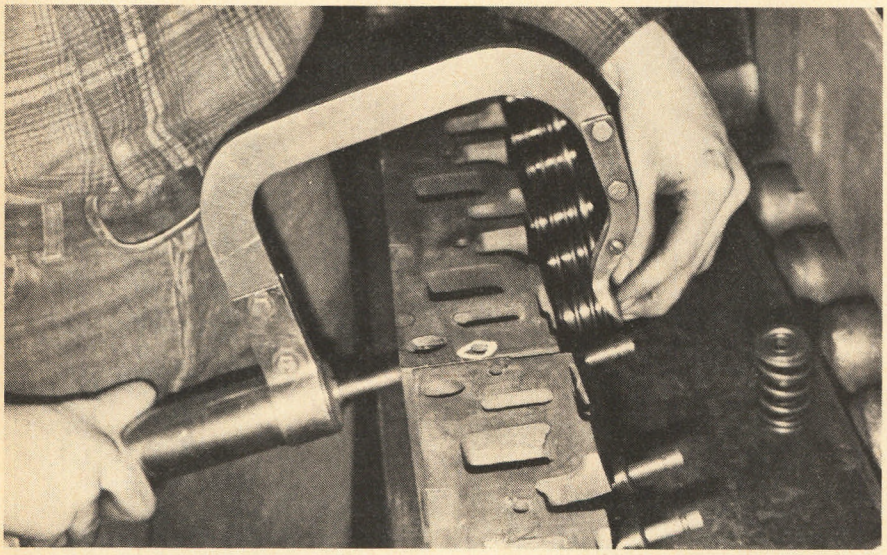
The small end of the rod must likewise receive attention. If the piston pin bushings are only slightly worn, they may be honed and oversized pins can be installed.

However, if new pistons are to be installed—and this is likely if the block has been bored—the new piston pins will probably be standard. Therefore new bushings will be required for the rod small end. Installing new bushings is easy, and it may be done with an ordinary vise. Care must be exercised so that the bushings enter straight and are not cocked. At the same time, any oil holes must be aligned. Thin-wall bronze bushings must be pressed tightly into the small end rod bore, and then honed to fit the piston pin.

There are two different ways that the piston pin bushing may be clearanced: by expanding hones, or diamond boring. A diamond boring machine is useful when a large amount of material has to be removed, but the best pin fitting is done with a honing machine. It can provide exact pin fits as close as .0001-in.

If a reamer is used, the bushing surface will not be smooth; therefore the pin must do the final fitting during initial operation. Because of this rough surface, a reamer pin fit is called either thumb or palm, meaning the amount of pressure required. A thumb fit requires less pressure than the palm, etc. Far better is the honed or bored bushing, where the fit is determined by clearances in ten-thousandths of an inch. As a rule, a pin will fall through a dry bushing of its own weight when the hole diameter is just right, but will drag somewhat when lubricated. If manufacturer clearances are not available, a rule of thumb is to use .0004-.0006-in. per inch of pin diameter. These clearances may vary according to type of pin action (full-floating, bushed, setscrew, etc.), so checking the engine manufacturer's charts is vital.

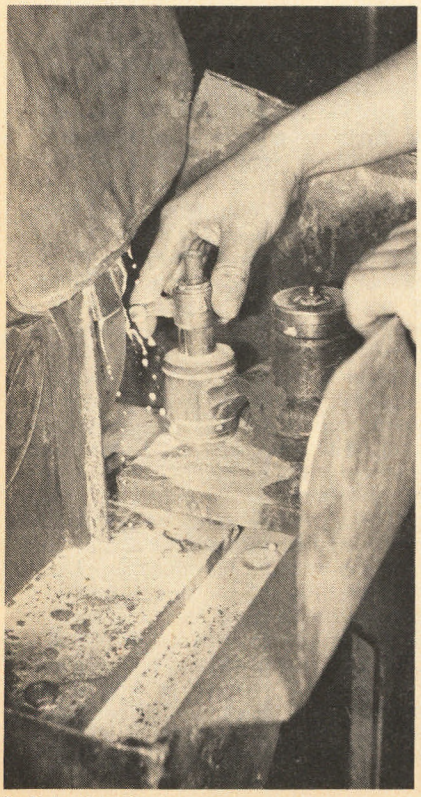
The full-floating piston pin design is finding great favor in modern engines, but the pin fit must be very close to perfect. As a rule, a bushed pin hole may use a slip fit of .0002-in. cold. Under normal engine operating conditions this clearance will increase to .0004-in., which is still acceptable for normal engine life.



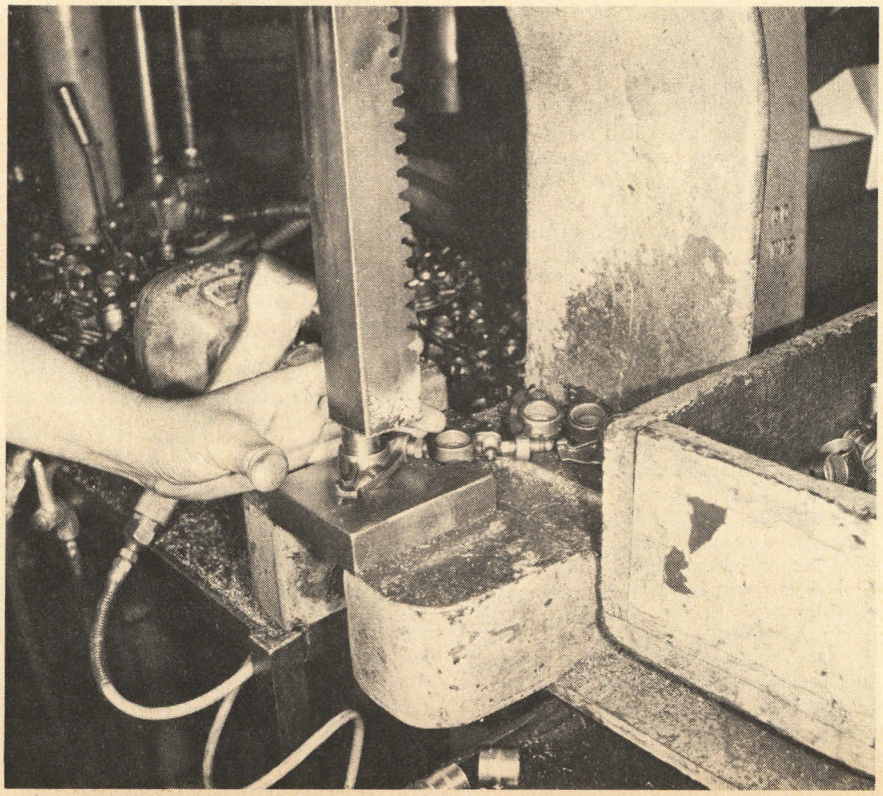
1. Using a Spring Compressor

PISTONS

If the cylinder bores are not worn



2. Grinding Rocker Arm Face



3. Pressing Out Rocker Arm Bushing

excessively, it is possible to reuse the same pistons with new rings. There is a limit to this economical repair, however, and if the engine has many thousands of miles on it, don't consider this.

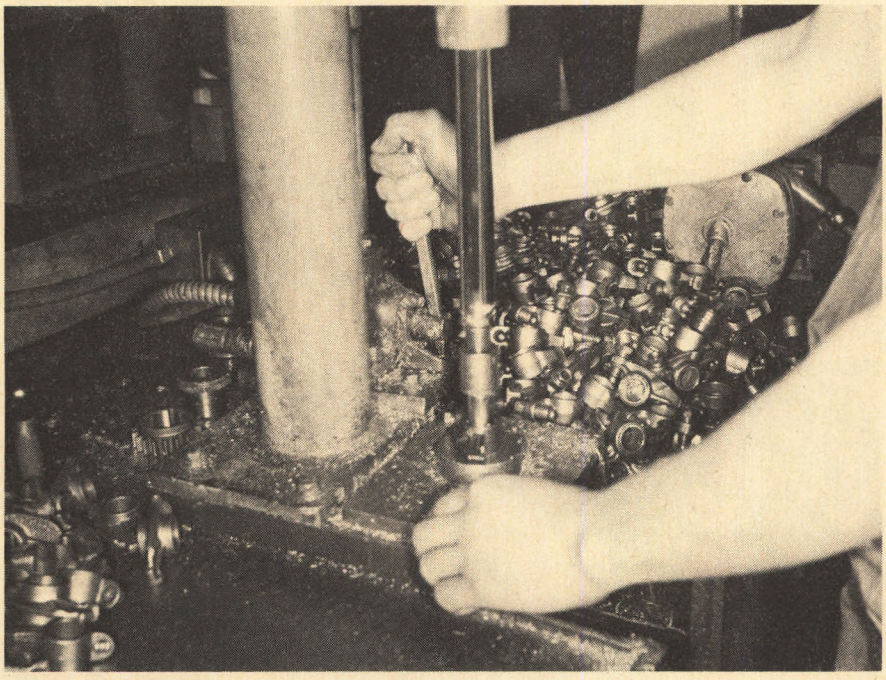
There are times, however, when nothing more than minor piston work is necessary. Sometimes, inferior rings are used in an engine, causing the rings to wear out too soon, and in this case a replacement is all that's needed. However, the wear of the rings in the piston grooves may require special piston reconditioning. Because the ring is trying to drag on the cylinder wall, it will work up and down in the piston groove until this groove is opened up, or widened. Excessive widening is normally restricted to the top groove, but if the lower two or three grooves open up, the piston must be replaced. If the top groove is widened, the opening will taper toward the outside. By cutting the groove with a special grooving tool this edge can be straightened out, and special spacers installed above the top ring. This is to keep the compression ring from traveling a fraction of an inch too high in the cylinder bore and striking any ring ledge.

If cylinder rebore is not necessary, but new rings must be installed, it may be necessary to also expand the piston skirts.

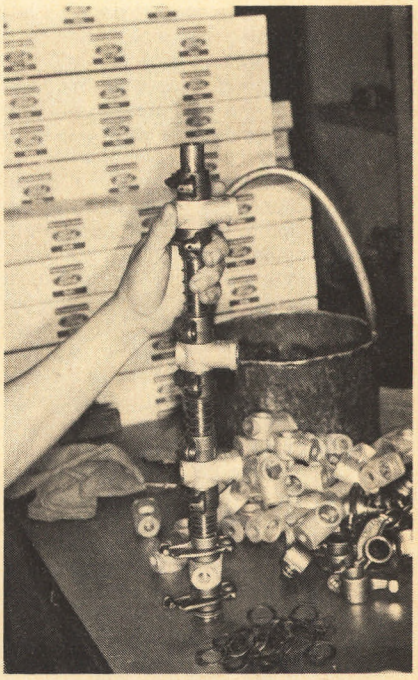
The most common method of expanding a worn skirt is by knurling. With this process, the skirt of the piston is given a waffle-groove effect. A tool forced against the skirt causes some material to displace, or squirt outward, effectively increasing the skirt diameter. Such a process can increase diameter as much as .008-in., often just enough to keep the piston from rocking in the bore and wearing the rings oval-shape.

There will be a difference in various piston designs. Some will be perfectly round and others will be cam ground; that is, there may be a difference in measurement across the thrust face of the piston versus the piston pin face. Such a feature will keep the piston quieter when cold, and allow expansion room when the piston reaches operating temperature. The amateur will seldom be faced with this as a basic rebuilding problem, inasmuch as the machine shop or original supplier will grind the pistons to size if necessary.

Whether the pistons are new or used, they should be carefully inspected for cracks, especially around the pin bore and the ring lands. Used pistons should



4. Pressing New Bushing Into Rocker Arm



5. Reassembly of Rocker Arm Shaft

1. An air-operated C-type valve spring compressor is used to hold the spring and seat down while locks are installed. For the tool fancier, this one's elegant.

2. Rocker arm radiused tip is just lightly touched to grinding stone. This trues up the face that operates on the valve stem.

3. New bushings are then pressed into rocker arms for a precision fit.

4. New rocker arm bushing is reamed to factory specifications and then installed on new rocker arm shaft.

5. Reassembly of the rocker and shaft assembly is done with new shafts, springs, etc. as these parts are usually too worn to be trusted. Quality control at Tomadur keeps rejection/return rate to a minimum.

6. A slight amount of metal is removed from the mating surfaces of the connecting rod cap, reducing the internal diameter of the rod and allowing the bore to be honed to its original size.

6. Grinding Rod Cap

Overhauling Engine

have the grooves cleaned and all oil holes unplugged.

Assembly of the rod and piston is a precision affair only in that care must be taken to get them together in proper relationship. Individual shop manuals must be consulted in this respect, since different manufacturers use different types of identification. However, if there is a necessity, the piston is identified in some way as to which is the front side and which should be toward the rear of the block. This is another reason disassembly should be thoughtful and careful. In general, the front top edge of the piston will be marked by a notch.

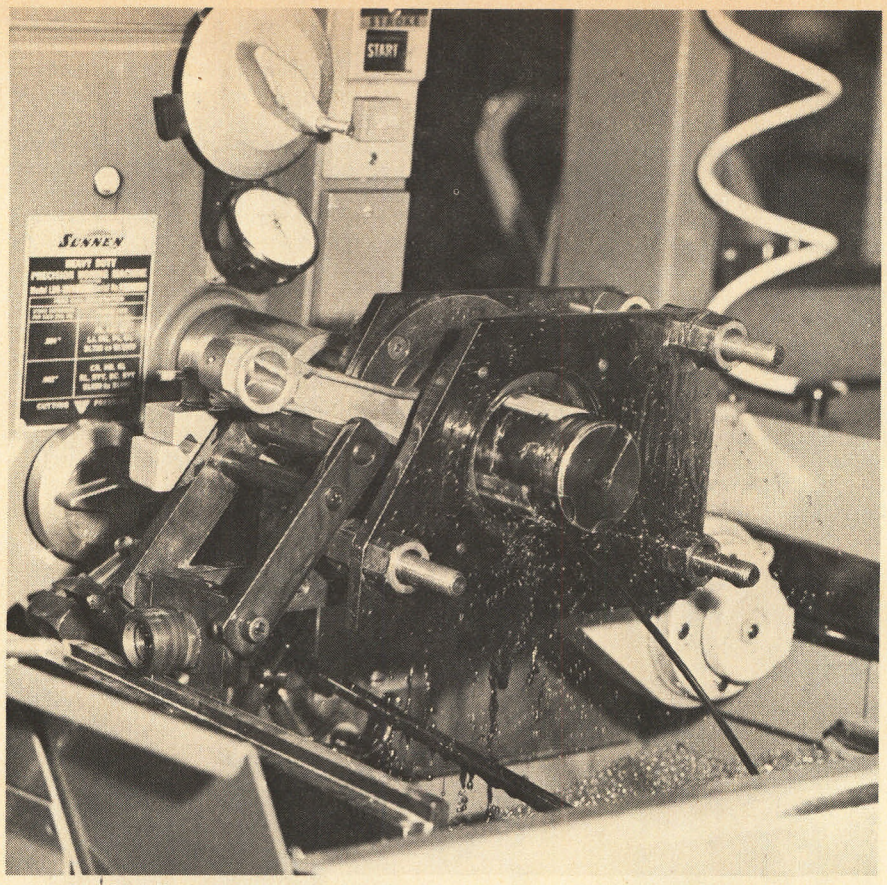
If the piston pin is retained by some sort of lock, make absolutely certain this lock is in place. Small nicks or burrs in the lock groove may cause it to seat improperly and cause serious damage later. When inserting the lock, squeeze it together only enough to slide into the pin hole. If it is compressed too much, it may take a set and not spring outward in the groove sufficiently. Always use new lock rings.

How well the engine performs after the rebuild will depend on how good a ring job the mechanic does. The modern automobile engine works under such severe conditions that every vital part must do its job correctly, and nothing is more vital than proper ring action. To achieve this with a rebuild, the correct replacement rings are mandatory. A brand-new engine works under considerably different conditions than a rebuilt engine. Rust and scale have built up on the coolant side of the bores until a different type of temperature range is occasioned; distortion will change with a rebore, etc. Therefore, it has been found that modern high-speed engines need something different in the way of rings than factory originals. As an example, any rebuild will generally include expander-type oil rings to control the oil under these different-than-new conditions.

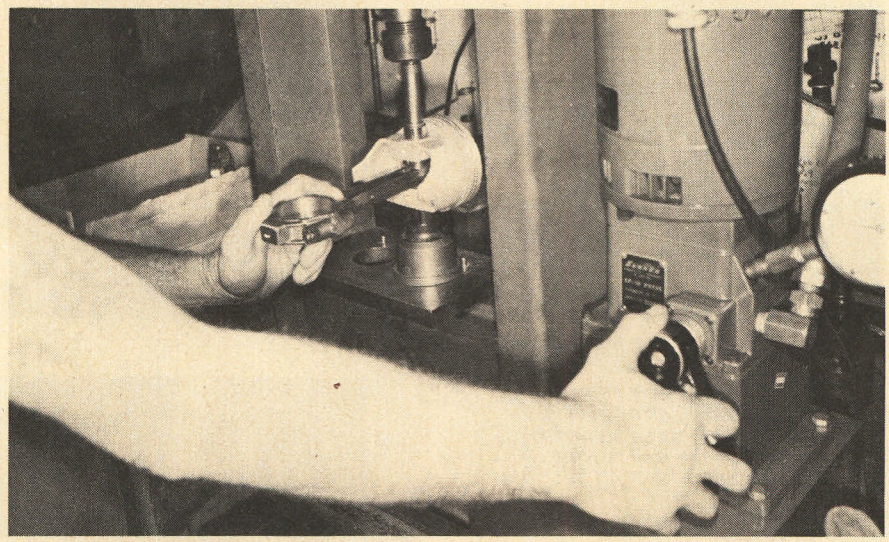
Rings are of three basic types: compression, scraper, and oil control. Another division separates the iron rings from spring-type expander designs, in that the expander rings are placed behind regular rings to force the latter more firmly against the cylinder wall and thereby aid sealing.

The compression ring has the prime responsibility of keeping the burning combustion chamber gases from reaching the lubricated part of the cylinder wall (this is called leaking down, or blow-by). The modern engine uses a tapered-face compression ring which will tend to slide over the oiled cylinder wall on the upstroke (thereby not pumping much oil into the combustion chamber), but will scrape excess oil off the wall on the downstroke. Such rings always have the top so marked, and this side must always be positioned up.

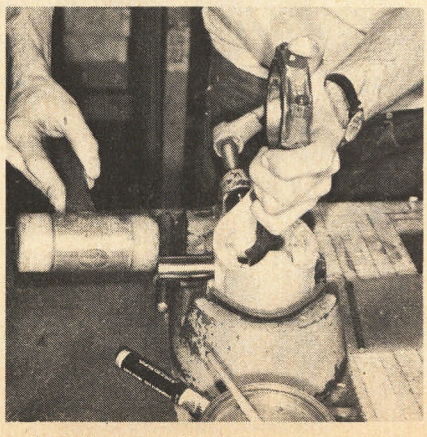
The second ring, or scraper, is used to help the compression ring. It scrapes oil on the downstroke and is a secondary seal against blow-by. There are several different designs of scraper rings, and in all cases the manufacturer's recommendations must be followed explicitly. The



1. Honing Rod Ends



2. Press-Fitting Pins



3. Installing Floating Pin

1. Honing restores bore to stock specs. Small end of rod is then bored, bushed, and honed to retain the stock center-to-center measurement.

2. Connecting rods in many stock engines are fitted with pressed-in wrist pins. Pin is a press-fit in rod but a slip fit in the piston.

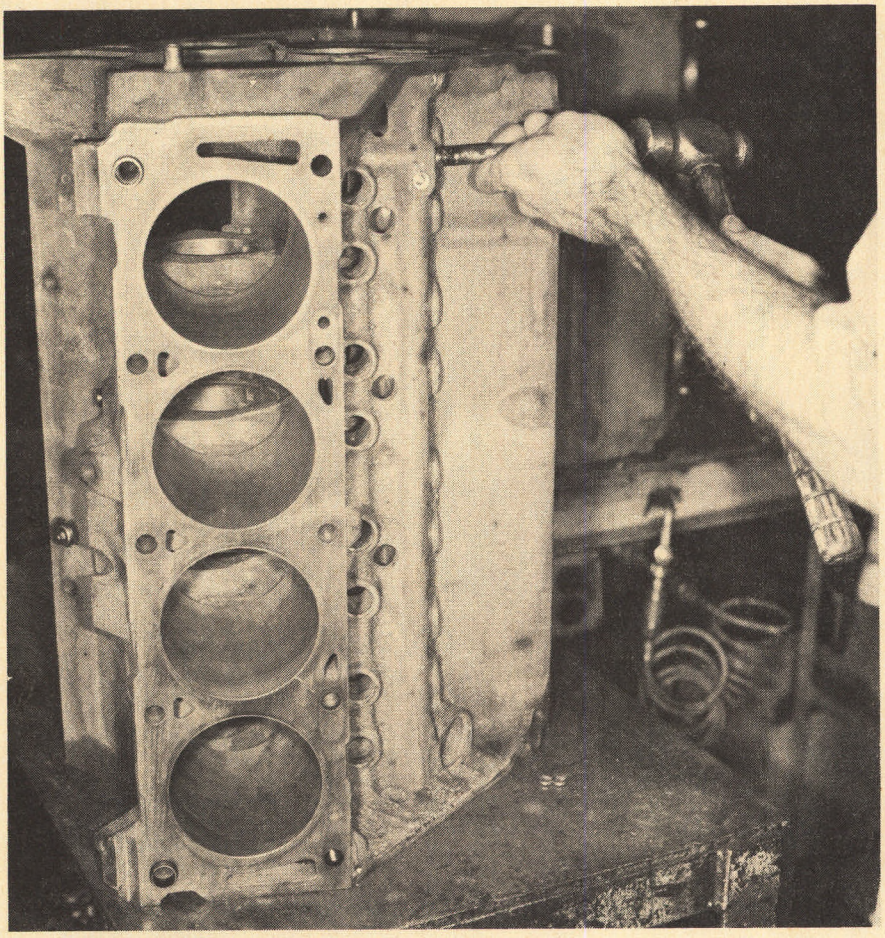
3. Floating wrist pins are tapped in place with a mallet.

4. Lock rings or pin retaining clips are inserted at ends of wrist pin.

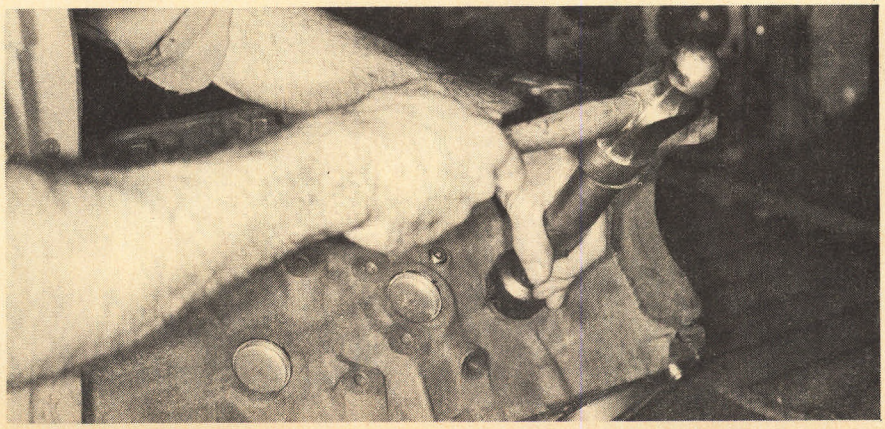
5. Actual block assembly begins with the installation of oil galley plugs.

6. Freeze plugs are seated by gently tapping in place as shown.

4. Installing Pin Retaining Clip



5. Installing Oil Gallery Plugs



6. Installing Freeze Plugs

oil control ring is designed to keep oil from entering the combustion chamber and varies in design depending upon the amount of oil control necessary. These rings are vented so excess oil can be sloughed through the piston and back to the supply point.

Installation of piston rings is a careful, methodical procedure, where sloppy work cannot be tolerated. Never assume that any new part is "just right" for the engine—always measure to make sure. With the piston, the ring groove should always be measured and compared with the requirements of the replacement rings as set forth by the ring manufacturer. Rings are produced to fit factory pistons perfectly, but replacement pistons may vary. Gauges for checking ring groove depth and width are available wherever rings are sold, and should be used. If the piston does have deeper than normal grooves, special expanders are available for the rings in a variety of sizes to counteract the difference. If the grooves are too shallow, it is best to regroove them more deeply.

Side clearance of the ring is absolutely imperative, and each ring should be checked along with each ring groove. On old pistons the ring groove will usually have worn until excessive clearance is the norm. New pistons, though, can have insufficient ring groove side clearance, which should be .002-in. for the top or compression ring, and .0015-in. for the remaining rings. To check this, slide a feeler gauge alongside the ring to the full depth of the groove. If the rings are slightly large, they can be reduced in thickness by rubbing them against a perfectly flat piece of emery cloth, then polishing with crocus cloth. Sand the top of the compression and scraper rings and the bottom of the oil ring.

Perhaps the most overlooked part of amateur engine overhauls is piston ring end-gap. This should always be checked, and each individual ring must be inserted in the cylinder bore during the procedure. Ring end-gap is normally .004-in. per inch of cylinder diameter for the compression ring, and .013-in. for the remaining rings. For a 4-in. bore, this would mean a .016-in. gap for the top ring, and .052-in. for the remaining rings.

This is a minimum clearance, and having too much is not a problem. Too little will allow the ring gap to squeeze closed, and broken rings and/or lands are the result. If the cylinders have not been rebored, always check this gap at the smallest portion of the bore, or the bottom of the piston travel. If the engine block has been rebored, the fit will be identical everywhere.

To check a ring, insert it about 1 in. down the bore and square it with the wall by tapping lightly with a piston. Measure the gap with a feeler gauge. If it is too little, remove the ring and run an end across a file. Be careful of the tiny parts, as the ends may break. As the rings are gapped, leave them in the cylinder bore until time to assemble to a piston, and mark that piston correspondingly. This will ensure the right rings per bore.

Placing the rings on the piston is a simple operation, but the novice may

break one or two in the process. Slide one lip down at a time if a regular ring expansion plier is not available, and work slowly. Installed, the ring gaps should be rotated 90° or more from one another, otherwise a straight-through gap is left for combustion gases. Multi-piece oil rings must also be treated specially during installation. Place the steel expander gap over a piston pin hole; place one steel segment with its gap 90° off, followed by the spacer or cast iron center section with a gap over the opposite pin hole; then place the final steel segment 180° to the first.

SHORT BLOCK ASSEMBLY

With the piston/rod assembly completed, the basic short block may now be assembled. There are various assembly lubricants on the market, and all work well. Remember that for the first few minutes a rebuilt engine is running, lubrication is super critical. Even when the oil pump has been prerun, oil will take a moment to reach the proper parts. An assembly lube will counteract this early starvation problem and should be used.

With the block upside down on a stand or dolly, wipe the main bearing saddles clean. A tiny piece of dirt behind the bearing will cause all kinds of bearing problems. Install the correct bearing half-shell in both the block and main cap, then install the proper cap to each block web. Lubricate the main bearing bolts with a good anti-seize compound, then torque each cap to the prescribed setting. Do not put assembly lube on the bearings at this time.

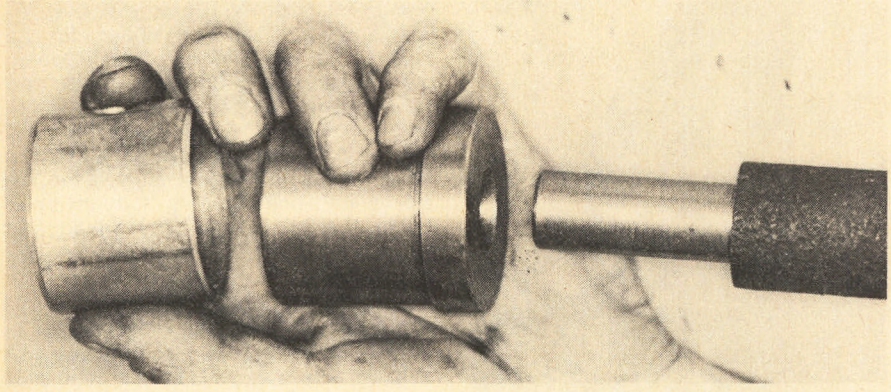
With an inside micrometer, check the inside diameter of each and every bearing bore, measuring both up and down and sideways. If everything has been correct up to this point, the measurement obtained should be the diameter of the crankshaft journal plus the prescribed oil clearance. This clearance will vary according to the individual engine, but the manufacturer's specifications should always be followed. In the case of main bearings, the clearance will be somewhere between .0015 and .0025-in. For rod bearings it will be from .002 to .003-in. If the engine will be used in high-performance or heavy-duty applications, oil clearance should be increased slightly, or run at the upper limit. Always consult a qualified mechanic or authoritative publication, such as *Hot Rod* magazine, for performance specifications.

The connecting rods should be assembled and checked in the same way. However, as mentioned previously, Plastigage may be used to check clearance, and if the mechanic is not sure of his mike-reading ability, this "actual condition" type measurement is recommended for best results.

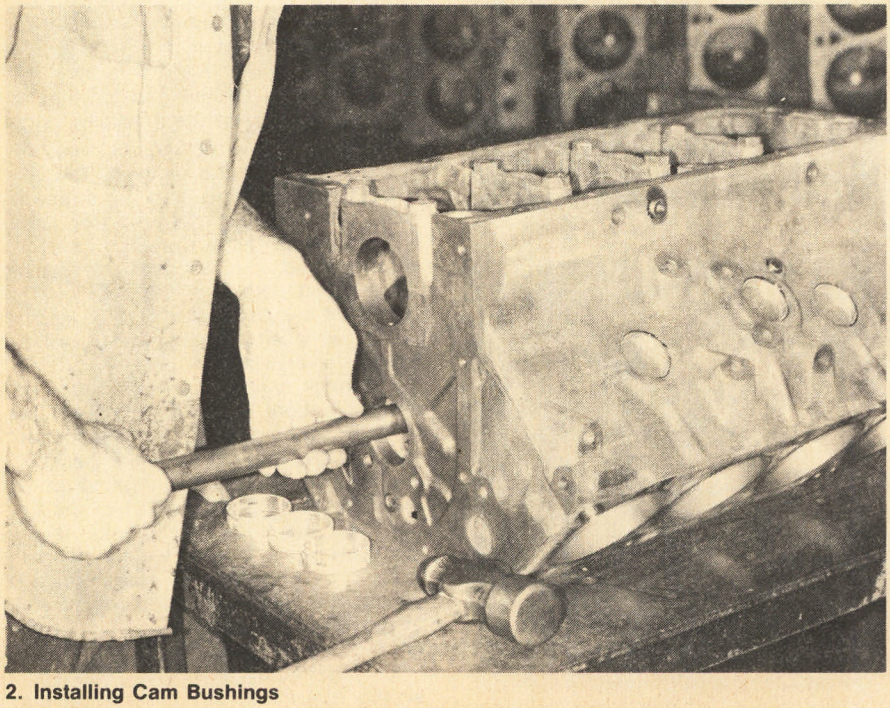
After main bearing clearance has been checked, the caps are removed and the bearing faces coated with assembly lube. The crankshaft is carefully laid in the block and the caps reassembled and again torqued to specifications.

The crankshaft should spin freely in the bore, without the slightest uneven drag. If it doesn't, something is wrong and work should not proceed until the trouble is found and corrected. Here is one place where the bent crankshaft and/or distorted block will show up immediately. Finally, check the crankshaft end-play, or the amount the crank can slide back and forth in the bearings.

End-play is checked between the crankshaft journal thrust collar and the main bearing thrust flange, using a feeler gauge to measure the distance. Pry the crankshaft away from the bearing surface. High-performance engines will



1. Cam Bushing Installation Tool



2. Installing Cam Bushings

1. Use camshaft bushing installer to install bushings properly. Tool fits all the way inside cam bushing.

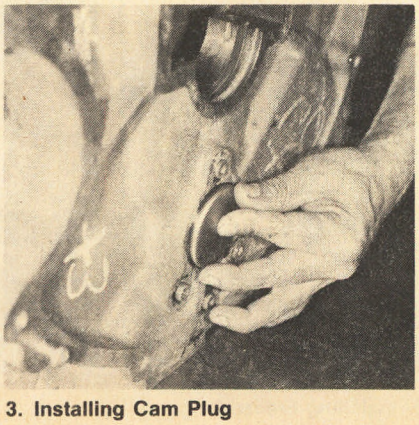
2. Bushings are installed from rear to front. Oil passage holes must line up with feed hole in the block or bearings will seize from lack of oil when engine is operated.

3. Once cam bearings are installed, new welch plug is fitted to back of cam bore. Plug's O.D. is coated with nonhardening sealer before fitting.

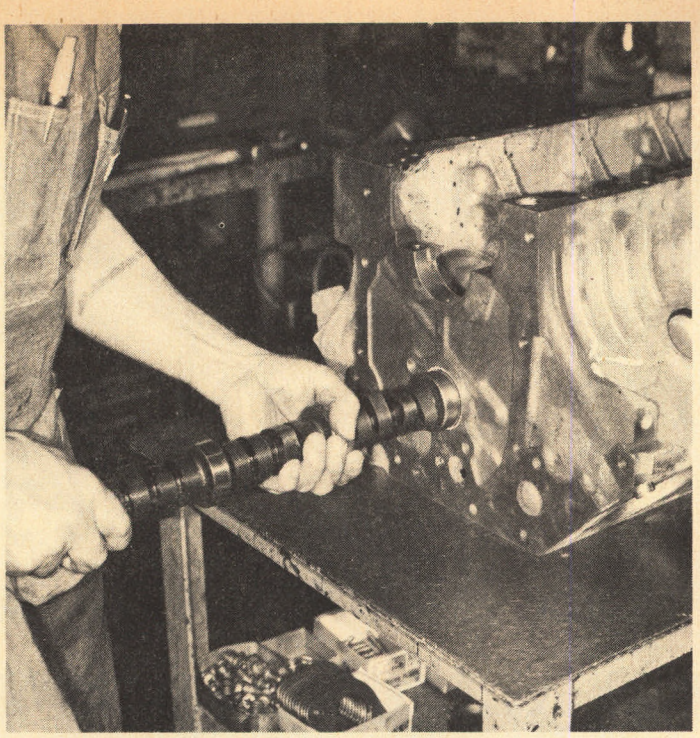
4. After removing the protective tape from the cam surfaces, it's carefully installed by hand to avoid marring the bearing surfaces.

5. Cam is seated completely by tapping into place. Note use of bolt screwed into cam face. This centers force of impact, as an off-center blow could mar the bearing surfaces as cam moves backward. Bolt is removed when cam is seated.

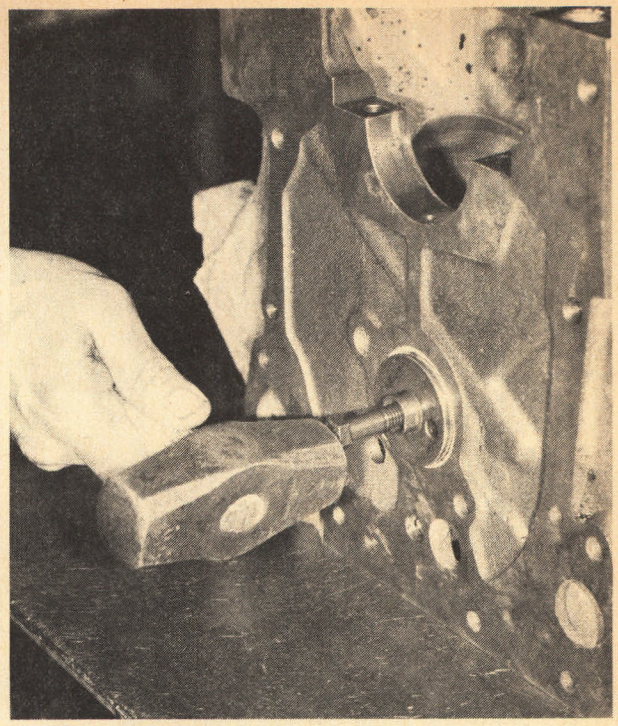
6. Camshaft retaining plate is secured in place and tightened with an impact air wrench.



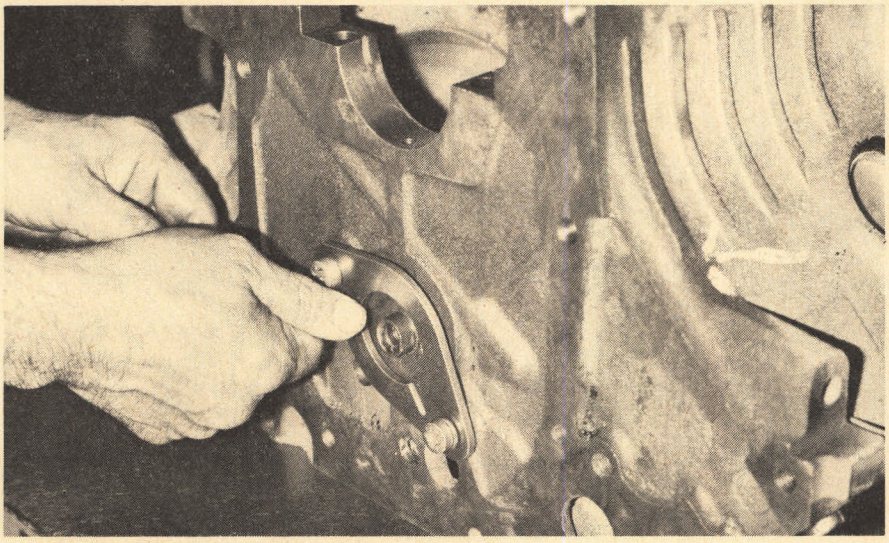
3. Installing Cam Plug



4. Installing the Camshaft



5. Seating Camshaft



6. Installing Cam Retaining Plate

have more clearance than stock engines, but as a guide, crankshaft journals from 2 to 3 ins. need .005-in. Journals of 3 to 3½ ins. need .008-in., and journals over 3½ ins. need .010-in.

Assembly of the pistons comes next. The pistons should be liberally coated with assembly lube, or dipped in oil, then a ring squeezer tightened to compress the rings. With the piston in proper position to the block, the piston crown is gently tapped with a hammer handle to force the assembly into the bore. It is vital that the rings be fully compressed into their grooves, or they will hang up on the entrance to the bore and may be broken. Revolve the crankshaft until the respective journal is at the bottom of its travel for each piston insertion, thus gaining working room for the connecting rod. After the last ring has cleared the ring compressor, the piston may be tapped through the bore until the connecting rod seats on the proper crankshaft journal.

For protection to the crankshaft, slip small pieces of rubber tubing over the rod bolts, and carefully guide each rod onto the journal. Once in place, the tubing is removed and the proper cap is installed. After all rods are in place, the caps are torqued to the correct specifications and individual journal side play is checked. This will not have changed normally, but if different rods or crankshaft from the original are involved, this should be checked during crankshaft preparation. This end-play is important to lubrication, and may be checked by inserting a feeler gauge between one rod side and the crankshaft cheek. If it is between .004 and .010-in., this is sufficient for stock engines. High-performance engines will need additional clearance.

Often overlooked by novice mechanics is the fact that oil on a bearing acts as a coolant as well as a lubricant. Oil enters the bearing through a delivery hole, is forced across the entire bearing surface, and exits through the clearance at each bearing side. As engine temperatures increase, the metal will expand. If the side clearance has been insufficient to begin with, the oil flow across the bearing is impaired until heat buildup is increased, failure is near. Too much side clearance is just as bad as not enough, since oil squirting out the side of rod bearings is used to oil cylinder walls, camshaft, and other components.

With the pistons assembled in the block, the crankshaft should still rotate without an uneven drag, although it will take more effort.

THE CAMSHAFT

The camshaft can be a real pain for the novice mechanic. It is one of those parts that wear in a most uneven manner, and unless carefully inspected will contribute to much head-scratching later on. A camshaft may have only one lobe slightly worn, and this will be enough to make the engine run slightly bad. The mechanic may suspect any number of causes before finding the culprit. The cam can twist, which will change the valve timing between front and rear cylinders. It is, therefore, to be suspect from the start of any engine overhaul.

Reconditioned camshafts are available through larger engine rebuilding shops, since they will never return an old cam to an engine. These cams are reground, and often rehardened if necessary, much as a crankshaft is repaired. Whether a new or reconditioned cam is used, the mechanic must be satisfied with spending a few dollars. This is one place it doesn't pay to be skimpy; simply reusing the old camshaft is merely asking for subsequent trouble from the entire valve train.

The camshaft rotates at half total engine speed, yet the very high loads imposed by the lifters make cam lobe wear a foregone conclusion. If an engine is

Overhauling Engine

running rough for no apparent reason, the ultimate cause may be traced to a single camshaft lobe that has worn round, thereby letting one valve loaf on the job. This is not at all uncommon on engines with many miles, and is particularly true of medium-to-high-performance engines.

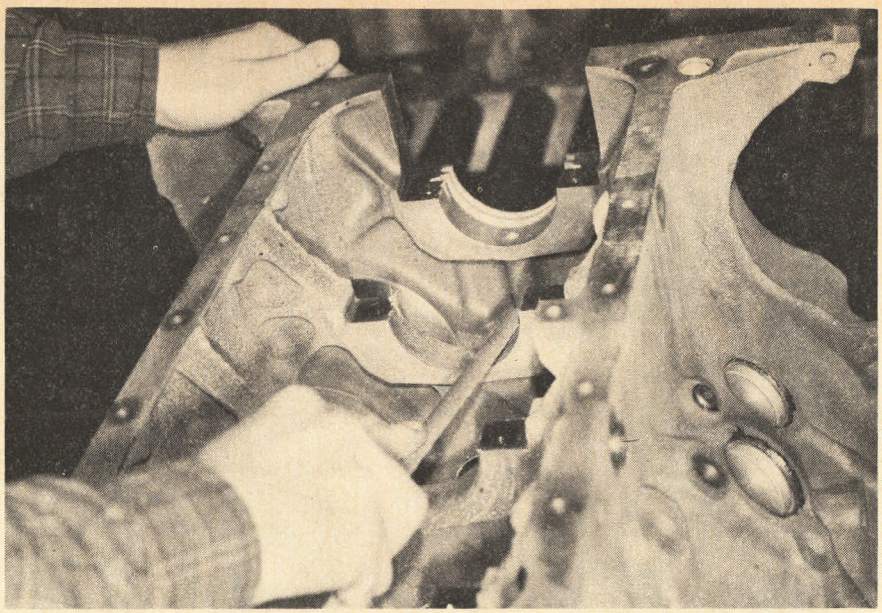
The selection of the proper camshaft has a direct effect upon how the finished engine will perform. If the engine is to remain stock, then a stock replacement should be utilized. However, it is possible to install a camshaft with different valve timing (the relationship of valve opening/closing to piston location in the cylinder). This does not automatically mean installing a high-lift racing camshaft. There are several different factory-type camshaft patterns available for the small-block Chevrolet engine, for instance (265 through 350-cu.-in. design), and each can actually be called a normal design. However, one will give better low-end torque, while another is better for higher speed operation.

Another example is the pre-1964 Oldsmobile V-8. The 1964 camshaft is an excellent all-around pattern, having been developed for a reasonably large displacement engine that must have both low-end torque and good cruising rpm. This cam can be fitted to any of the earlier Olds V-8's (lifters must also be used), and is superior to any of the earlier cam designs. It costs no more than any of the previous camshafts. As a guide, pick an engine of the same type as that being rebuilt, then investigate the factory parts manual for camshaft specifications. If a 283 Chevrolet V-8 is being overhauled, it is entirely possible to use a camshaft from one of the milder performing Corvettes, and in one simple operation to update the older engine performance.

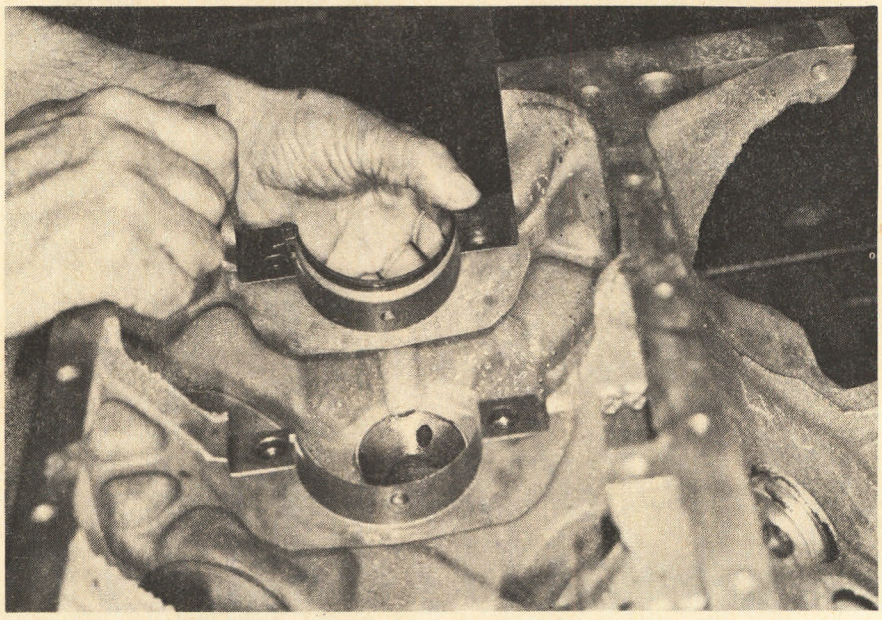
When the engine block was being cleaned, the camshaft bearings were removed, either by a drift punch or a special puller. If the engine was placed in a caustic immersion bath, the bearings would have been eaten away and useless anyway.

New bearings can be put in at any time, but care must be taken to get the bearings installed properly. Coat the outside of the bearing with engine oil to help installation, and make sure the oil supply holes in the bearing are aligned with those in the block. And make certain the right bearings are being used! Most mechanics install cam bearings with drift punches, firmly tapping each one into place, but the tapping is done on a steel plug that fits inside the bearing, with a shoulder that pushes on the bearing shell. The edge of the bearing must not extend beyond the bearing bore, or it may come into contact with a rotating cam lobe.

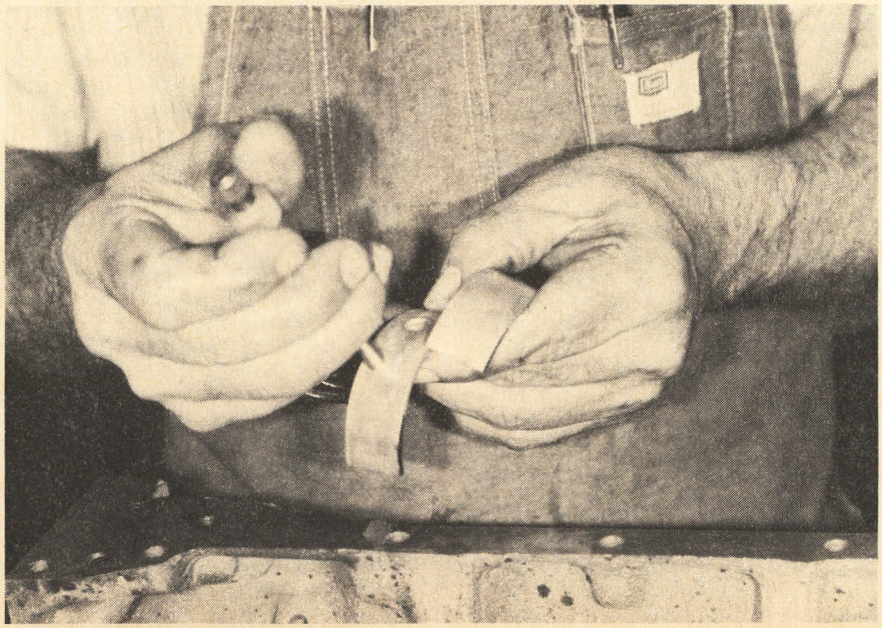
After the bearings are in place, coat the inside diameter with assembly lubricant, and very, very carefully slide the new camshaft into position. There are from three to six bearing journals on a camshaft. After each one has passed through a bearing, there is nothing but the mechanic to keep the sharp lobe



1. Deburring Main Bearing Seats



2. Installing Main Seal



3. Miking Main Bearing Shell

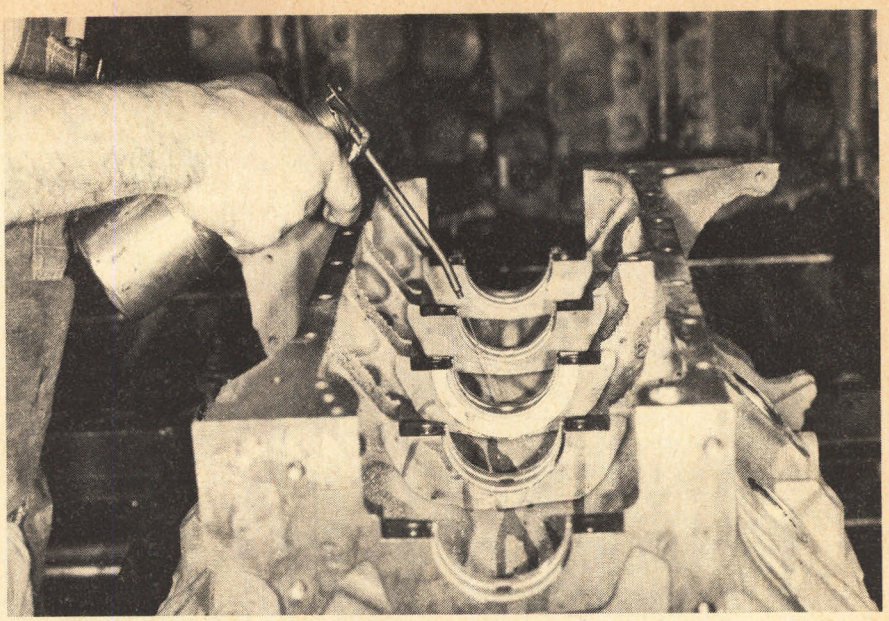
1. Crankcase bearing seats are lightly filed to remove any burring that might affect bearing performance.

2. Crankshaft bearings are inserted from the rear, beginning with the rear main bearing oil seal.

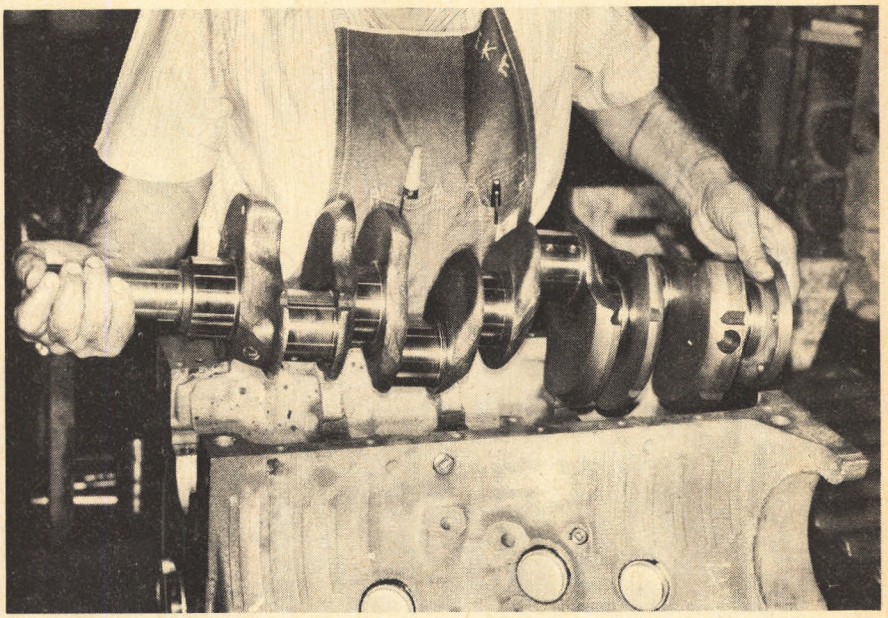
3. All bearing shells are miked before installation. While this should not really be necessary, even the factory occasionally fouls up.

4. Plenty of lubricant is in order to protect the bearings and crank surfaces until oil is pumped through block when engine is first fired up.

5. The clean crankshaft is lowered into the bearings with care, then turned to make sure that it's free. Little friction should be felt, as crank is not secured.



4. Lubing Engine Bearings



5. Installing Crankshaft

edges from tearing up the bearing surfaces. Go slow and easy.

A camshaft will try to wind out of the bore—that is, move forward during running; therefore, some kind of thrust retainer will be involved. It may be a plate that bolts to the block, or simply a rub surface on the timing gear cover. Whatever is used, must be used. Camshafts have end-play specifications just as crankshafts, and should be checked in the very same manner.

If the original camshaft timing gear is in good shape, it may be reused, and is held in place by a Woodruff key. Sometimes a bolt is also included. There will be a timing mark on the front of the timing gear, near one of the teeth, and a similar mark on the crankshaft gear. In some cases correct valve timing is achieved by placing these marks directly opposite each other, and in others there are a specified number of teeth between the sprocket marks.

To set the timing in the first type (called timing marks on center), merely rotate both crankshaft and cam until the respective marks are closest to each other and on a direct line. In the second method of timing, turn the crankshaft until two timing marks are toward the left side of the engine; then adjust the timing chain so that the correct number of sprocket links are in the chain between the crankshaft gear mark and the camshaft gear mark. The timing chain cannot be installed if both gears are already in place, therefore the camshaft timing gear (the big one) is positioned to the correct timing location within the chain (the chain already being positioned on the crankshaft gear), then the timing gear is slipped onto the camshaft register and secured.

Timing of an engine has a tremendous effect upon final performance, and being off one or two teeth will be enough to keep the engine from ever running as it should. However, this is one of the basic precepts of hot rodding and is utilized by all the racing engine builders. Do not attempt any timing modifications to a stock engine without consulting an expert!

Whether or not the timing chain cover is installed at this point depends upon how it mates with the oil pan. In some cases the timing cover must be in place before the oil pan is installed, but most American cars have independent timing covers and oil pans.

OIL PUMP AND PAN

While the camshaft may be correctly termed the heart of an engine's performance, the oil pump and lubrication system may aptly be called the center of mechanical longevity. Just how long an engine will run depends entirely on lubrication, and the oil pump starts the entire cycle. In this respect it is a cast iron heart pumping a petroleum blood stream.

Location of the oil pump may vary from one engine design to another, but the average system has the pump driven by the camshaft, or at half the engine rpm. This is accomplished by placing the actual pump somewhere in the pan cavity (or low on the outside of the cylinder block), and providing the drive through an extension of the distributor driveshaft. The driving gear which meshes with the camshaft may be on either the oil pump or the distributor.

Two types of pumps are in normal passenger car use: the rotor type common to Chrysler products, and the gear type on Fords. Both obviously do the job, and the only real difference is in the operating clearances. Since they are literally bathed in oil most of the time, mechanical wear is less likely than with other engine parts; still the shaft and end plate must be carefully checked and repaired or replaced if needed.

Wear is most common to the end plate, and if this exceeds .001-in. (wear or warp), the plate must be replaced or machined smooth. Anything under .001-in. wear can be dressed out with emery cloth. To check the clearances of a gear-type pump, place a straightedge across the housing and gears, then slide a feeler gauge between both surfaces. If the distance is greater than .003-in. either the gears or housing must be replaced (whichever is worn). The gears should clear the pump body by a maximum of .005-in. Such tight tolerances are imperative if the pump is to operate correctly.

Overhauling Engine

The rotor pump looks much different from the gear type, having a 4-lobed cam working inside a 5-cavity secondary rotor, but the end plate clearance must also be .003-in. or less. One of the primary rotor lobes must be pushed into a secondary rotor cavity as far as it will go, then the clearance of the lobe exactly opposite must not exceed .010-in. as measured between the primary lobe and a high spot on the secondary rotor. The outer, or secondary rotor is perfectly round, but since it also rotates, clearance between it and the stationary housing should be a maximum of .012-in.

There are no special assembly instructions for oil pumps other than those contained in repair kits, which may include special clearance gaskets for the end plate (necessary for proper end float of the gears/rotors). However, there should be between .003 and .009-in. end-play between the drive gear or shaft retainer and the stationary housing neck.

Use a gasket between the pump and the cylinder block; do not use any kind of sealing compound. The pump may be primed with oil before it is attached to the engine, but more on preliminary lubrication later. It is absolutely vital that the oil pump pickup tube and screen be perfectly clean before reassembly. If the tube or screen rotates in any way, it must be free to do so without binding, and there should be no air leaks in the pickup tubing. Incidentally, the size of the pickup tube has been engineered for a particular engine, so any interchange of tubes may be a detriment unless the inside diameter is the same.

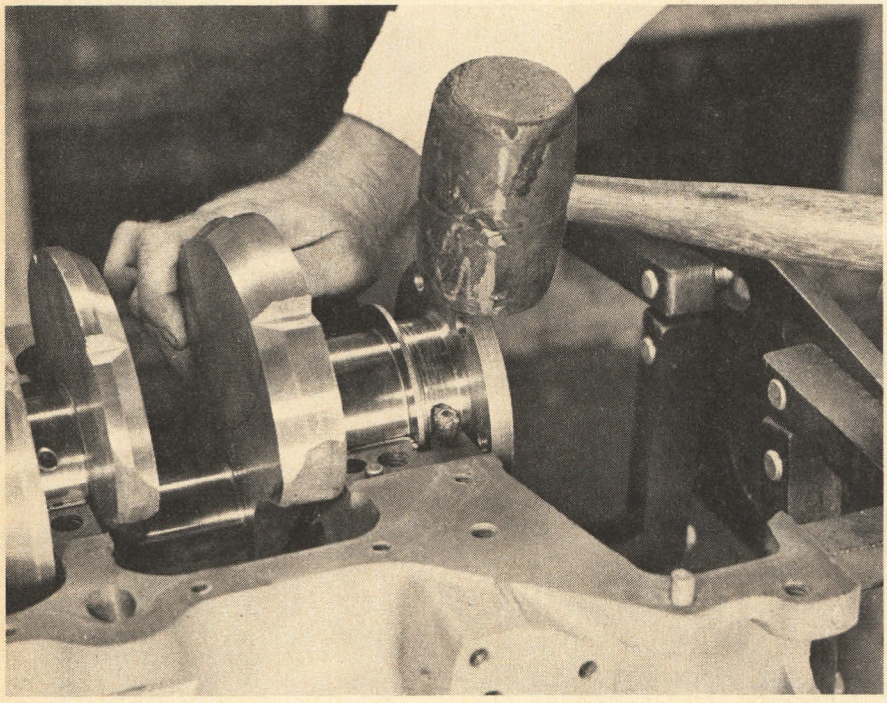
Oil pans as supplied on any engine are designed to do a specific job. The only consideration that might be given to a different, or modified, pan would be to increasing the capacity or including additional baffles. Added capacity will be helpful if the engine tends to run hot (remember oil is a coolant), and baffles will keep the oil from sloshing away from the pickup screen on hard acceleration, deceleration, or violent turns. Such modified pans are common to race cars of every type but not necessary on ordinary passenger cars.

Unless the pan has been damaged by rocks, it will bolt back to the block with no trouble. Gaskets must be included along each rail and at each end, usually attached with a good sealing compound. Do not overtorque the pan bolts, as the light sheetmetal will easily distort and won't seal well.

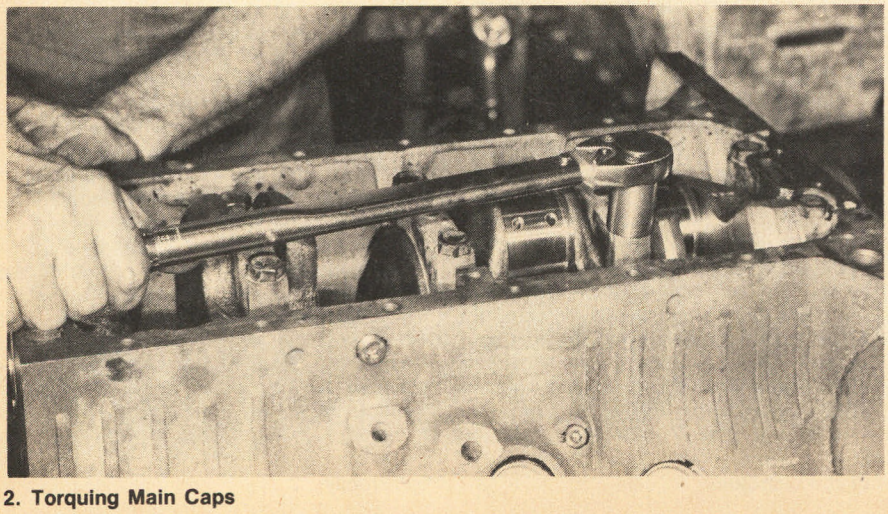
After the pan is installed, the harmonic balancer or the crankshaft pulley, or both, may be bolted to the crank snout. These pulleys are often cracked or bent, so replacement should always be considered if the unit proves to be bad. The oil filter finishes work to the bottom of the engine, which may be turned over now to complete work on the top portion.

HEADS

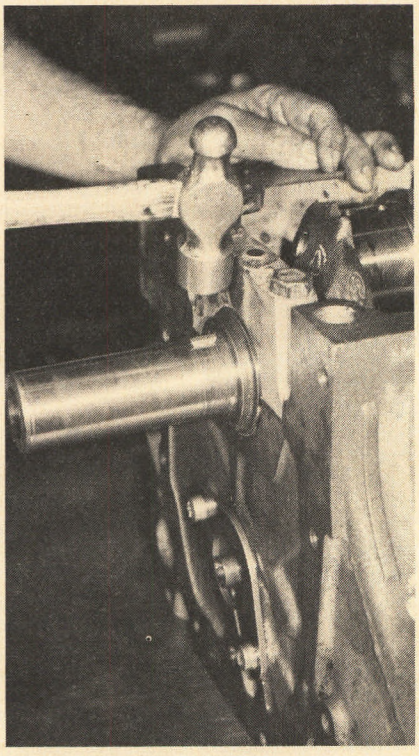
Overhaul of automotive heads is almost a special repair project unto itself, since heads play such a vital part in an engine's performance characteristics.



1. Seating Crankshaft Seal



2. Torquing Main Caps



3. Installing Woodruff Key

1. The rear crank flange is gently tapped with a rubber mallet to seat the rear seal. If this is not done, the crank may not rotate once the bearings are installed tightly.

2. Bearing inserts are put into main caps and oiled, then caps are fitted in place and torqued down to factory specs.

3. Tapping Woodruff key in at front of crank finishes installation.

4. Pin pressed into camshaft timing sprocket will fit into cam, assuring that sprocket turns with cam.

5. As crankshaft sprocket is seated in position, timing sprocket is fitted to face of cam.

While the cylinder block, crankshaft and piston assemblies are responsible for changing energy of the burning fuel into mechanical advantage, the cylinder heads are directly involved in the creation of that initial energy. Whereas the other parts mentioned (known as the basic block, or lower end) experience mechanical wear for the most part, the heads are subject to tremendous forces associated with combustion: intense heat, high pressure loads, rapid changes in temperature, etc. At the same time, overhead valve head components experience mechanical wear that is difficult to control. It is a significant tribute to the automobile engineer that problems as this have been successfully solved.

Basic head repair is of a distinct mechanical nature, with emphasis given to valve seats, cracks, distortion, and valve guides. Obviously, these are problems attendant to the overhead valve engine only, since the flathead has the valve mechanism in the block.

A cracked cylinder head may be caused by several factors, such as water freezing (expansion), combustion (pressure), distortion (bolt torque), or running without water (expansion again). Of these, combustion and excessive heat (running without water or detonation) are the common villains. For this reason, head cracks are generally confined to the immediate combustion chamber/valve seat area, and are difficult to repair. Although there is a set procedure for such repair, this is one job that should definitely be left to the professional, as he will have both the experienced skill and the tools to do a good job. As long as the crack is within the valve seat area—that is, normally well into the port and partially in the combustion chamber—the repair is not too difficult. However, a severe crack in the top of the combustion chamber caused by excessive pressures or a mechanical malfunction (dropped valve, etc.) will usually mean a new head.

Discounting cracks, the amateur can do as good a head overhaul as the professional, providing he takes time and works thoroughly. After the rocker arm assembly has been removed during initial disassembly, the only moving parts left on a head are the valves and springs. To remove them requires a special compression C-clamp, one end holding the valve head and the other pressing down on the valve spring. In this way, the valve spring may be depressed enough to remove the split keeper retainers. It's simple with the right tools.

As each individual valve/spring retainer assembly is removed, it should be kept together, particularly the valves. Mechanics use a yardstick drilled full of holes as a handy valve organizer. If the valves are in reasonably good shape, and the valve guides in the head are not worn excessively, each valve should return to its original location—all because each valve/guide combination will not have the same amount of wear as the others. Under such a condition, average repair calls only for valve and valve seat refacing.

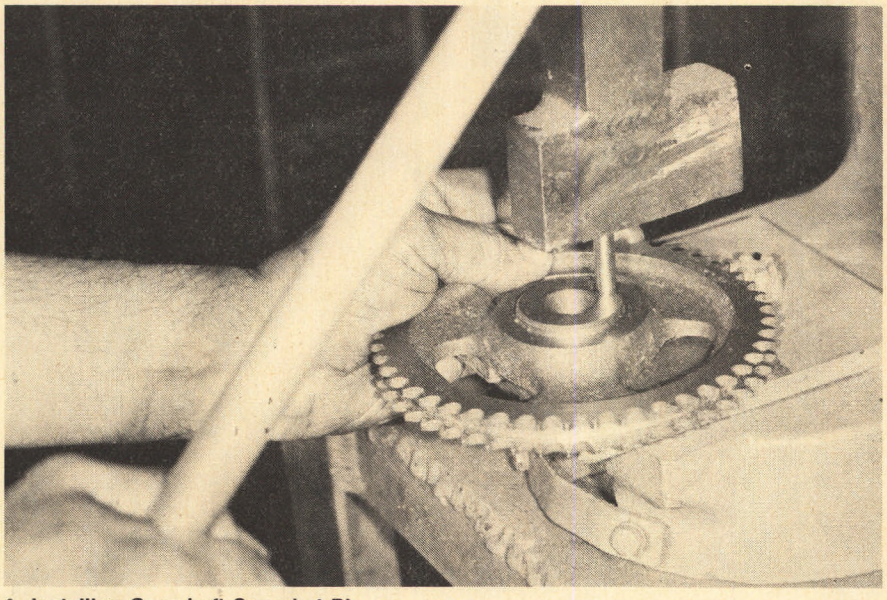
With the valve assemblies removed and the spark plugs taken out, there is nothing left in the head that can come out, with the exception of the valve seats and possibly the guides. Both will require attention in a general overhaul of an engine with many thousands of miles.

Before work is started on either of these areas, the head should be thoroughly cleaned. This consists of chipping away all carbon deposits in the combustion chambers and ports, either with a sharp instrument (putty knife, screwdriver) or a rotary wire brush. This is a time-consuming job at best, but should not be overlooked. Oil passages should be cleaned with the small wire brush, and blown clear—a procedure that should be duplicated before reassembling the head.

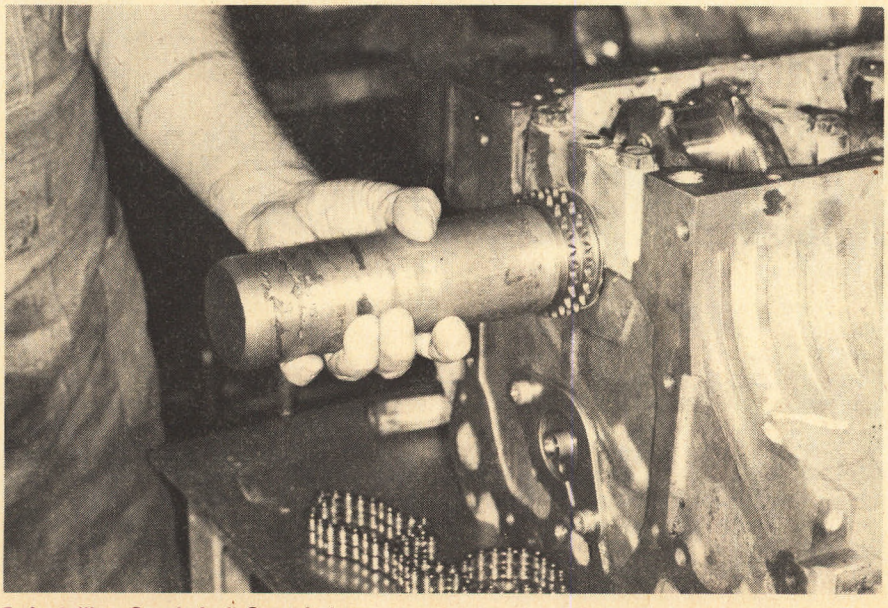
If valve guides are worn, the valve can hardly be expected to do a good job. Wear is caused by the standard rubbing of metal against metal, a factor aggravated by difficult lubrication requirements. The intake valve stem is constantly being washed by the fuel mixture, and the exhaust valve stem is subjected to intense heat. Add to this the fact that a guide is just that—it must guide the valve in a straight line while the force moving the valve is working through an arc. The tip of the valve stem in contact with the rocker arm is being pushed up-and-down as well as back-and-forth, therefore guide wear is likely to occur in a slotted fashion in line with the force exerted by the rocker arm.

Before guides are replaced, the originals should be measured to see how far each protrudes into the intake or exhaust port. These special shaped bushings can be pressed out, or driven out by hammer if a special punch is available. Replacement guides are available in a number of different metals, depending upon the punishment they must take.

Contemporary engine designs are leaning toward the integral head/guide system, wherein the head metal is also the guide. This kind of approach has several advantages, one being reduced valve temperature as heat is whisked from the valve stem more easily, and another is lower production cost. However, when an integral guide wears, it



4. Installing Camshaft Sprocket Pin



5. Installing Crankshaft Sprocket

cannot be replaced. Instead, valve stems are made in oversizes, such as .003, .005, .015, and .030-in. In this way, the worn integral guide is reamed to the next applicable size, allowing for clearance. This takes special tools, however, and is usually left to the machine shop.

Another type of guide repair, or modification, that has been finding favor with high-performance engine builders is guide knurling. Just as knurling the skirt of a piston will effectively increase the diameter of the piston, so will knurling the inside diameter of a guide decrease the I.D. The guide may be reamed to a larger true size, then knurled back to stock clearances. An advantage of this procedure is the creation of hundreds of small oil traps in the guide wall, which will give better stem lubrication. This, too, is a machine shop operation.

Clearance is a very special problem with guides, and the specified measurement for a particular engine should be adhered to exactly. Excessive clearance around an intake valve is a sure way to encourage high oil consumption. A good insurance against oil sucking into the combustion chamber is the valve stem seal, a nylon insert that fits around the valve stem on the rocker side of the head. These are reasonably priced and easy to install.

No engine overhaul should be attempted without at least refacing the valve and valve seat. It may be nothing more than a touch with the grinding stone, but it is essential to a successful job. While some engines seat the valves directly against the head or block metal, most designs call for specially hardened valve seat inserts shrunk into the head.

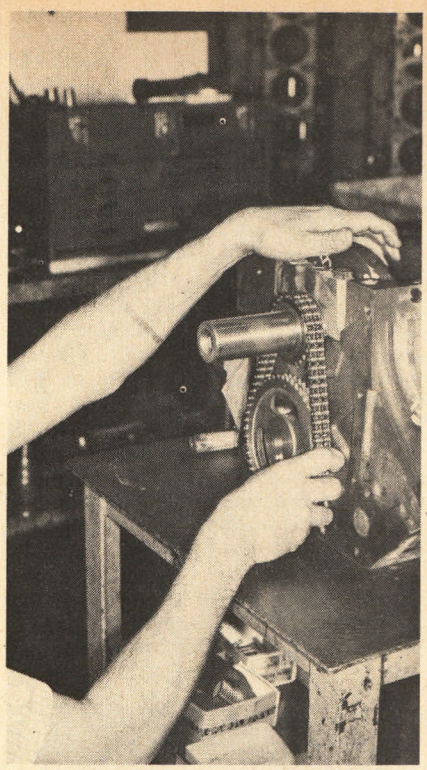
These inserts must be carefully checked, as they crack, and may be loose in the block/head. A loose insert, or one that is cracked or burned beyond repair must be replaced. They can be punched out from the back side (through the port), or pried out with a curved bar. They are brittle and the small pieces fly in every direction when they break, so place a rag over the pry bar and wear protective goggles.

The insert does not fit a perfect hole in the head. Instead, the machined depression is an interference fit, from .005 to .008-in. smaller than the diameter of the insert. From this it is obvious the head must be perfectly clean or the little insert won't insert so well. On the other hand, a loose insert will allow carbon to build up around the edge. Although this is such a tiny bit of insulation, it is sufficient to keep the exhaust valve from transferring heat to the head rapidly enough. A burned exhaust valve is next on the list.

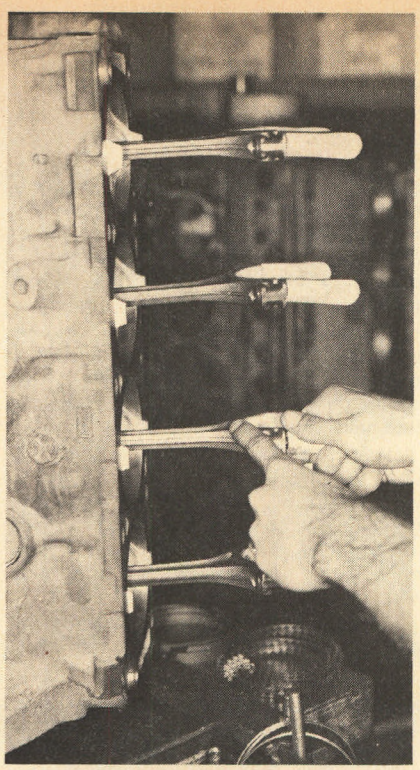
If the original insert hole in the head is the proper size, a new insert can be set in place "as is." Otherwise, the hole must be machined to the next insert oversize. To make insert installation simple, place the unit in a freezer. This will shrink the metal more than enough and it will drop right in place. When the insert warms to room temperature it will be tightly wedged in the block or head.

Valve seats must be ground by a tapered stone. It is absolutely essential that the pilot shaft fit the guide snugly. Too loose a fit allows the stone to wander; this is one reason the guides are reconditioned or replaced before the seats are fixed.

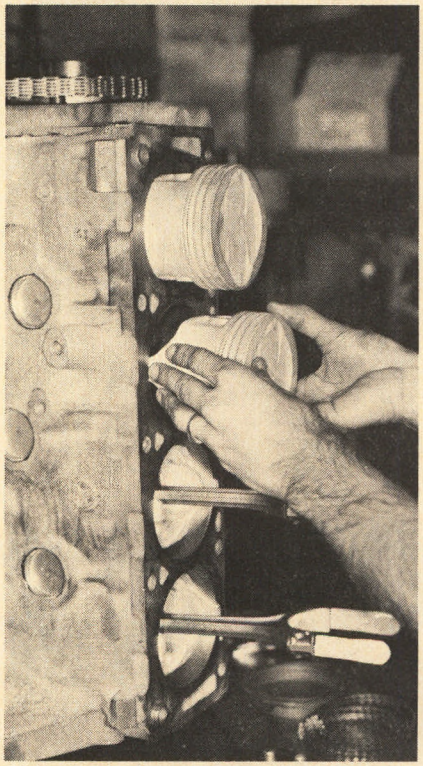
It is possible to rent seat grinders, but since accuracy is essential, such a grinder may not be the best. Fortunately, machine shops and professional mechanics are well equipped for valve work. So this job is a snap for them, and if the head or block is disassembled, the cost is quite low.



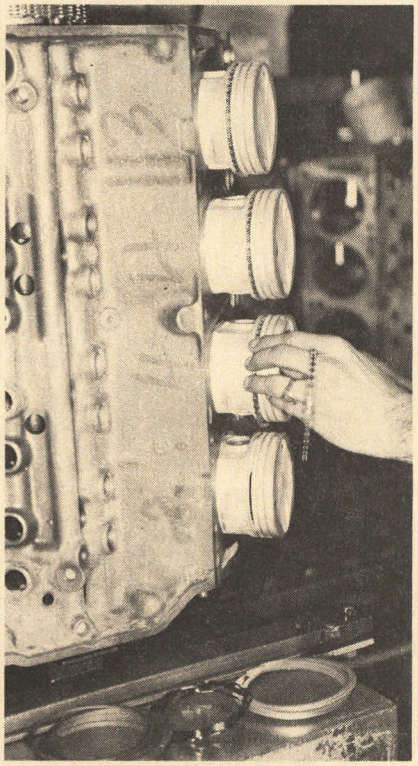
1. Aligning Timing Marks



2. Protecting Rod Bolts



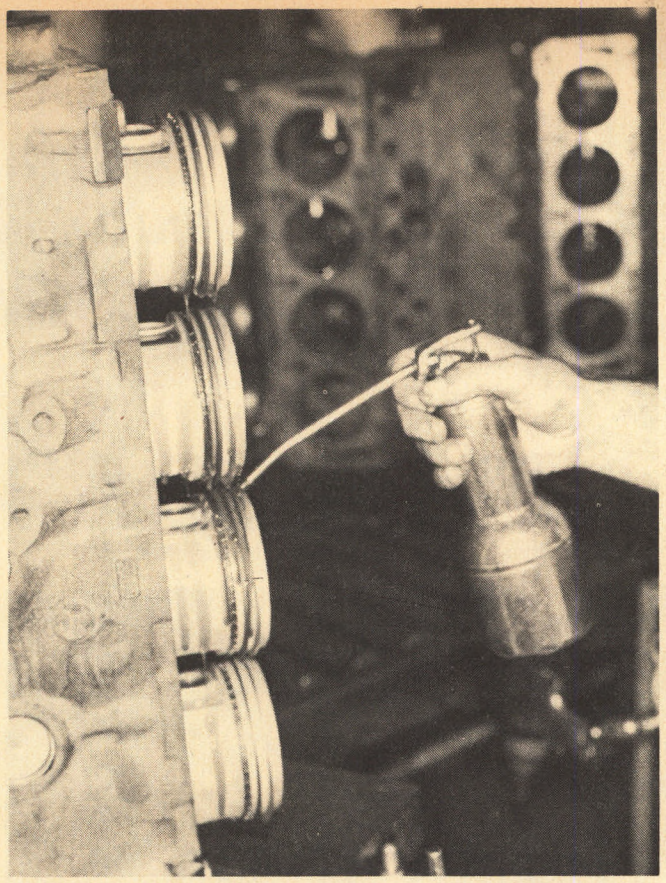
3. Installing Pistons



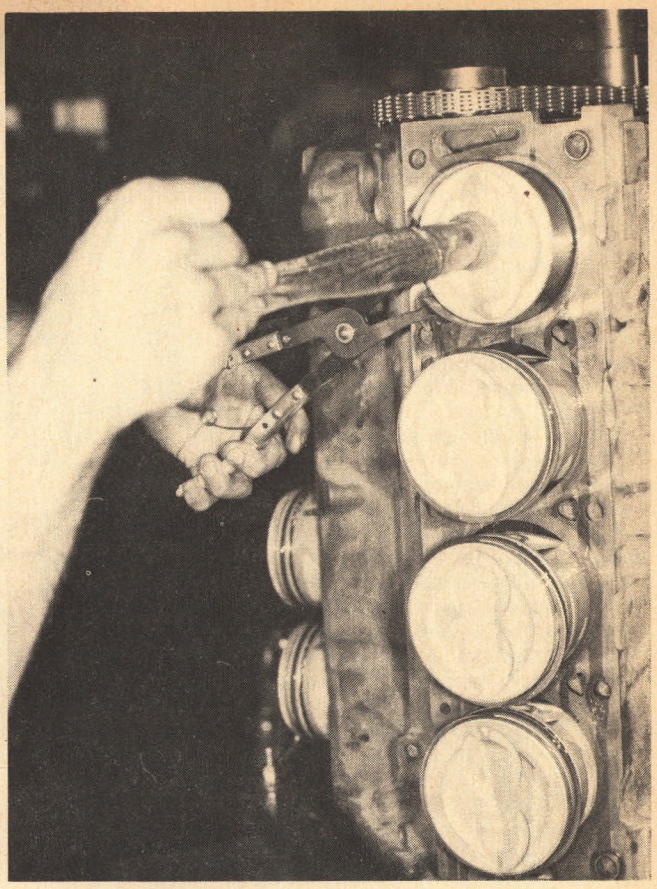
4. Installing Piston Rings

Valve seat grinders usually come in a case, complete with a full range of stones of varying angles. The most common angle is 45°, with some 30° designs still in existence. It is imperative that the stone be dressed before use, to insure maximum accuracy (seats should not exceed .002-in. off-center, and can be checked by a dial indicator).

A soft touch is required when you're using a seat grinder. Do not press down. In fact, you should support the weight of the driving motor with your hands. To do a good job, raise and lower the grinder



5. Oiling Piston and Rings



6. Using Ring Compressor

1. Timing chain completes crank/cam assembly and block moves to next station for piston installation.

2. Pistons are inserted wrong way in cylinders while rubber "fingers" are fitted over rod bolts. This protects crankshaft when pistons are inserted properly.

3. Pistons are then reversed to proper position in preparation for ring installation.

4. Working from bottom toward top of pistons, rings are positioned on each one. End-gaps are alternated 90° to lessen chances of blowby.

5. Plenty of lubricant is applied before seating the pistons in bore.

6. With the piston set in block and facing the right direction, the compressor is held tight against block and piston tapped lightly. If not held tight, the rings will pop out of the compressor before they are in the cylinders and are likely to break on the block.

about twice every second. This will let the stone revolve at high rpms, and the cut will be made rapidly. It only takes a few seconds to true up a valve seat (Stellite is different—it takes several minutes because it is so hard to cut with a stone).

A coarse stone is used for the initial grinding, then a fine stone to finish the seat. Because any grinding of the seat face will also widen it, a third stone with a greater angle is used to face the inside or outside diameter of the seat and return it to the correct width. This width is quite important and should not be overlooked. Exhaust valve seats should measure between .090 and .100-in., while intakes are .070 to .090-in. The exhaust valve has more heat and, therefore, it has more contact area to transfer heat better.

Final head work includes grinding away any sharp edges inside the combustion chamber. The threads of the spark plug holes are an example of this, and although not absolutely essential, this just makes a good job better. The head must be checked with a feeler gauge and straightedge for warpage.

VALVES

The automobile engine is a bag of serious compromises, and the engineers have been able to perform seeming miracles over the years in making an internal combustion engine as efficient as it now is. Part of the problem stems from getting the right amount of fuel mixture into the combustion chamber at precisely the correct time, then effectively sealing that chamber for subsequent fuel burning and expansion. It all boils down to some kind of valve in a 4-stroke engine.

Inventors have spent hundreds of thousands of hours trying to develop a better or more efficient valve, with the list including sleeve valves, rotary valves, poppet valves, slide valves—and still the search continues. In the interim, the standard poppet valve as we know it continues to be developed to ever greater degrees as engine performance requirements continue to increase.

Operating conditions for a poppet valve are brutal, to say the least. Unlike the other parts of the engine, a valve is exposed to intense combustion temperatures with almost no chance to cool off. While the head of a piston is also exposed to these high readings, it can pass off heat through the skirt and the rod, as well as the surrounding water-cooled cylinder block—the valve should be so lucky! Instead, it must have a large-diameter head (to give maximum breathing capacity for best performance) and a small stem. Heat can therefore be passed along only through the tiny stem and during the very few moments of each revolution when the valve face is in contact with the valve seat. Considering that explosion temperatures inside a combustion chamber may reach 5000° F. for a split second, the task would seem impossible. Furthermore, the poor old exhaust valve must open at the most inopportune time and pass the hot gases out the exhaust port. This is why valve jobs are so common to an engine that is in otherwise excellent running condition, and why keeping the valves adjusted is so vitally important.

Temperatures of a valve head may reach 1000° F. or more under these conditions, and certainly higher for racing engines (racing engines use exotic valve materials). It is easier to understand just how difficult a job the valve has when you consider how short a time the valve is seated. If the engine is turning 3000 rpm, or the average cruising speed of most cars, it means that one of the several cylinders will have ignition 1500 times per minute, and that means the valves are off the seat the same number of times. Not very much time for a valve to cool off.

While the seating surface area of the

valve head may only reach 1000°, the center will be 200-400° hotter and the stem just below the head slightly below the 1000° F. This is red hot in any language. If the valve does not seat against the insert exactly right, due to a bent stem or a piece of foreign material, the edge will burn immediately. Once decay starts it spreads rapidly. The intake valve does not have these great temperature problems, because it is seated when the heat is being passed out, and the incoming fuel mixture is at or below atmospheric temperature.

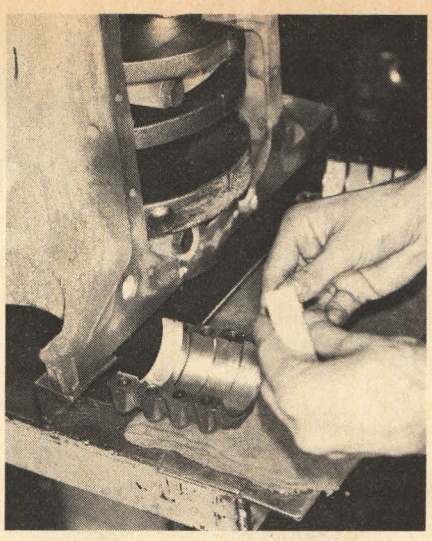
Because of the extreme temperatures involved, exhaust valves are normally made of heat-resistant alloy steel. Sometimes the stems are made hollow and filled with mineral salts such as sodium, which is a fast heat conductor. All the exhaust valve's operating problems are further aggravated by operational changes in the engine. The engine may be in perfect condition cold, but when it warms up to running temperatures, some kind of distortion is likely to occur. This in turn may cause localized hot spots near the valve, with attendant heat problems transferred to the valve. The metal may distort enough to slightly misalign the valve between guide and seat, causing an improper heat transfer, and so on. All this just goes to prove that valves are one of the most important areas of engine overhaul, and must be treated with care and precision.

Of course, if the deposits on the upper part of the valve stem (just below the head) could be minimized, this would in turn cut down on the chances of a valve sticking slightly open—and most of the valve problems would be over. One way to reduce the effect of such deposits (caused by the combustion particles sticking to the exhaust valve as they flow out) is to have the valve rotate slightly each time it is lifted. There are two types of rotating valve designs currently popular, one called the free-type wherein the valve rotates at no particular rate, and the other (called a Rotocap system) where the valve rotates an exact number of degrees each time it is opened.

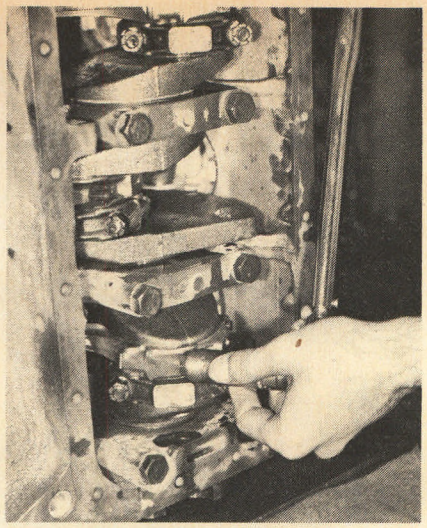
The amateur mechanic is faced with a basic problem when it comes time to do the valves. If they look to be in good shape before disassembly, then it would seem reasonable to reuse them with no refacing. This is just asking for trouble. It's like putting on three new tires, and leaving a fourth one bad. A valve job should be part of any engine overhaul.

Valves may be lapped if precision grinding equipment is not available, but this is not the best procedure. To lap a valve, special grinding compound is placed on the seat and the valve is rapidly rotated back and forth against the seat. The required tool is a rounded handle with a small suction cup that sticks to the valve head in order to turn it.

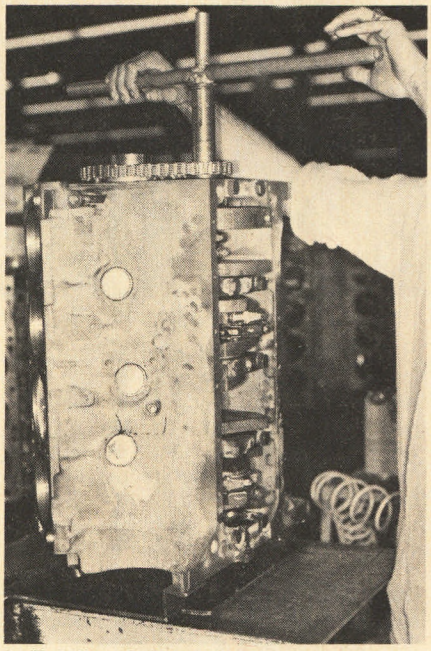
There are two kinds of compound available: coarse and fine (the fine is preferred). They come in either oil or water mixtures (use water to remove excess of one, solvent for the other). When lapping a valve, use a very small amount



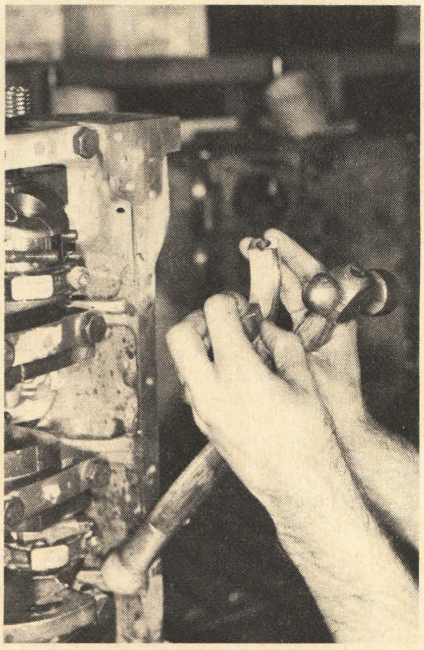
1. Installing Connecting Rod Bearings



2. Torquing Connecting Rods



3. Rotating Crankshaft



4. Checking Rod Bearings

under the valve head, as it can work down around the clean stem and be just as effective at opening up the guide clearance. Inspect the valve face often, and when a small, even, gray ring appears the full circumference of the face (the width of the seat) the job is finished. Of course, there must be no pits or nicks in the mating surfaces.

Lapping is inferior to precision grinding in every circumstance, and never should a precision-ground valve be mated to a lapped seat, and vice versa. As a guide, restrict valve lapping to conditions where precision grinders are not available, or the valves are in nearly perfect condition to start with.

Ordinary passenger car valves have reasonably thick heads, making it possible to reuse burned valves. When the grinding equipment refaces the valve, it also trues the head and usually very little must be taken from the face to remove minor pits and burn traces. If the valve has burned badly, however, it must be replaced. Normally, there will not be more than one or two badly burned valves involved, since the car will run so poorly with just one bad valve.

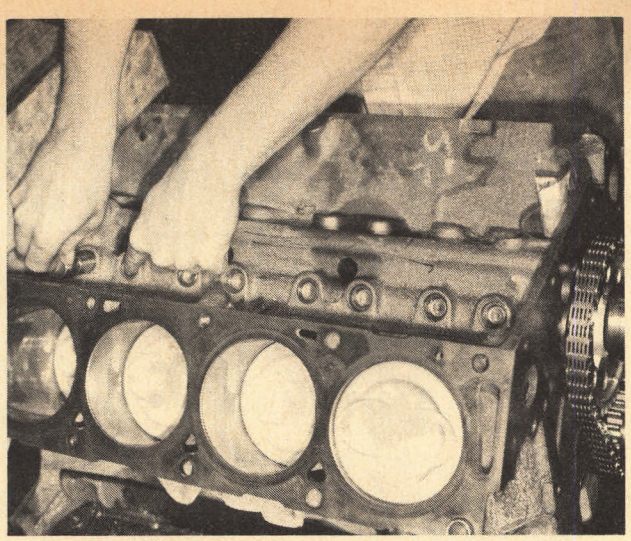
After the valves have been ground, they must be cleaned of any stem deposits. The heads are also cleaned, and it is time to assemble the valves in the head.

ROCKER ARMS

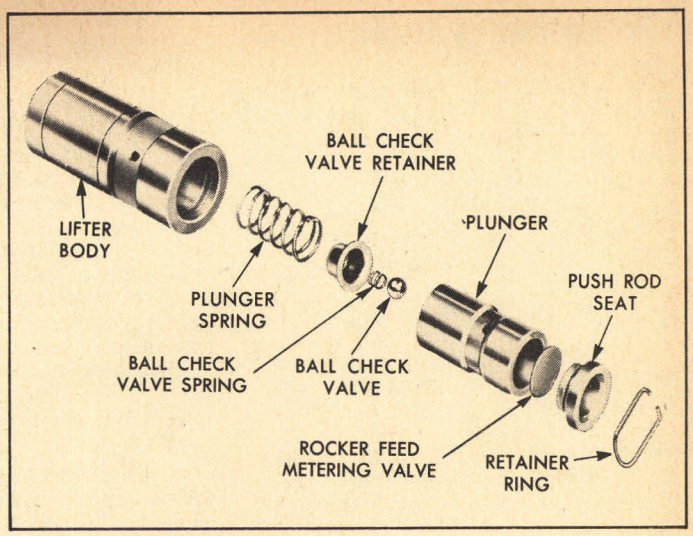
As with valves, rocker arms also can and do wear rapidly. They should be carefully inspected for wear at three points: where the valve tip touches the face, the shaft bushing, and the pushrod stud. The stud ball tip may be worn away, or the adjusting threads may be bad. Repair to all these areas may be made by the mechanic, but a cracked or bent rocker arm should be replaced.

If the rocker face is pitted, it may be dressed flat. While such a unit could be retained and the valve lash adjusted with a dial indicator, this would not solve a basic wear problem. If the face pitting seems excessive, it is possible the rocker arm material is faulty.

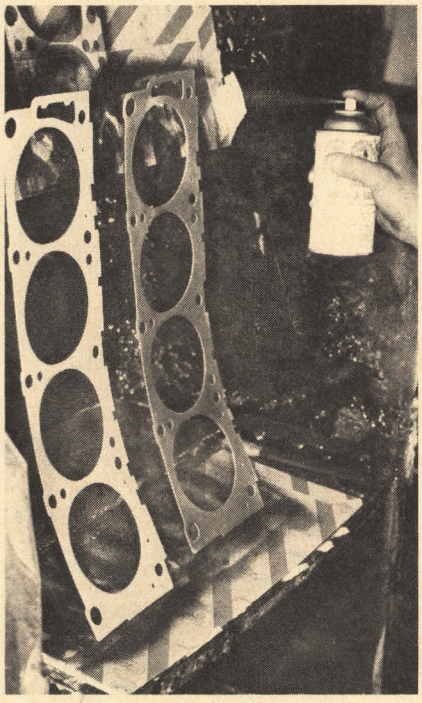
It is not uncommon for the adjusting stud threads to break or gall in the rocker, so these should be run through with a screwdriver several times as a check.



5. Installing Hydraulic Valve Lifter



6. Exploded View of Lifter



7. Spraying Head Gasket

1. New connecting rod bearings are fitted to caps before installation.

2. Caps are torqued to factory specs. New lock nuts are used here.

3. Crank is turned to work pistons, once piston/rod assemblies are in.

4. Each rod cap is removed and bearing surface checked after crank has been turned several times.

5. New lifter assemblies are installed. While lifters can be disassembled and tested for their leakdown rate, new ones are really inexpensive in a rebuild situation.

6. The plunger spring in hydraulic lifter keeps the plunger and pushrod seat up against the pushrod. When lifter body is raised by cam lobe, oil trapped underneath ball check valve lifts plunger and opens valve.

7. New head gasket set is sprayed with a gasket adhesive sealer just prior to installation.

The slightest bind means some kind of trouble. If the lubrication has been poor, the stud ball end may have become pitted, and in extreme cases will even wear away in the pushrod socket.

Because both the valve spring and the pushrod are always forcing the rocker upward, all wear of the rocker bushing and the rocker shaft will be on the bottom side. Such wear is readily apparent and common to engines with many miles. To inspect for the wear, force the rocker to the side with a bar. If the shaft is worn, it will show as a ridge of metal riding in the bushing oil groove. Worn shafts should always be replaced, and used with new rocker arms.

When reassembling the rocker and shaft assembly, it is often difficult to get the rockers in the correct place, since exhaust and intake rockers may be of different lengths or shapes, or both. To circumvent this, leave one shaft assembled while working on the other. This is a good guide as to how things are supposed to be put together.

Don't overlook the rocker shaft supports, as they often break from excessive bolt torque.

PUSHRODS AND LIFTERS

Cam-in-block overhead valve engines use pushrods to connect the camshaft/lifter assembly and the rocker arm. Overhead cam and flathead engine designs do not have the pushrods. A pushrod should be inspected for wear or warpage and discarded if either is found. Wear will be found where the rod enters the lifter, or at the upper end that contacts the rocker adjustment (some engines do not have an adjustment if the lifters are hydraulic). A slight pit in the lower ball or the upper socket is a sign of trouble, so replacement is suggested.

Lifters come in two versions, solid (mechanical) and hydraulic. The solid lifter is nothing more than a cam lobe follower, but it has been precision engineered for that purpose. The hydraulic lifter is a different breed of horse.

The hydraulic valve lifter is designed to keep a zero-lash clearance—that is, to reduce engine noise there is no clearance between the cam and ultimate valve stem. If this were the case with solid lifters, the expansion of the metals would cause the valves to remain slightly open during running temperatures. With the hydraulic lifter, any lash in the system is compensated for by hydraulic (oil) action. A hydraulic lifter has three basic parts: the body (housing), plunger, and valve.

Oil from the main oil gallery passes through the lifter check valve, forcing the plunger up from the bottom and into contact with the pushrod, and ultimately the valve stem. This oil is under pressure determined by metering holes in the lifter and the oil gallery.

As the lifter is raised by the camshaft action, there is a further pressure on the trapped oil inside the lifter. This closes the check valve and the lifter then becomes a solid lifter for all practical purposes. A tiny amount of oil is allowed to leak from between the plunger and the housing during this open valve phase so that when the cam rotates to the closed position, the valve will not be kept slightly open by an over-full lifter. This lost oil is replaced again by oil from the gallery. When an engine with hydraulic lifters is first started, a clattering sound from the lifters indicates that one or more have leaked completely dry and will take a while to pump up again.

It is possible to wear out lifters of this type, although the plunger movement is very small during operation. Dirt, varnish, carbon and similar foreign materials can get into the lifter and cause the check valve to stick. Keeping the engine oil clean and free from either physical or chemical contamination will make you and the lifter great friends.

Economics of engine rebuilding being what they are, novice mechanics often try to "get by" with the old tappets when a new cam or complete overhaul is involved. Good luck. Most modern engines have been designed to include revolving lifters, and this means that lifter-to-camshaft lobe contact points must be absolutely correct. Most cam problems stem from incorrect lifter contact (the contact point should be slightly off center to the "high" side of the lobe).

Camshaft lobes taper from one side to the other, usually betw en .002 and .004-in. The face of the lifter is ground slightly rounded, or about .002-in., and

by placing the lifter bores slightly to the higher side of the cam lobes, each revolution of the camshaft will cause the lifter to rotate a few degrees. If either the cam lobe or the lifter face are not ground correctly, or have flattened during use, this rotation is nullified and rapid wear in one spot will result.

VALVE SPRINGS

Valve springs are especially susceptible to life-span problems. Spring steel being what it is, operating under even ideal conditions, will not ensure perfect spring life. Therefore valve springs can be expected to fail from time to time since they must operate in unfavorable conditions.

Each and every valve spring should be checked for tension on a special reading scale. The spring must be measured for free (unloaded) height. If this is in the limits prescribed for the particular engine (line them all up together and a comparison check will show minute differences in height), then the spring is compressed a certain distance. At this distance the coils should be exerting a certain amount of pressure. If not, shims may be required between spring and head, or spring and retainer, to get the prescribed pressures.

At the same time, the coils of the spring must not bind against each other, or the spring will break during use. If the springs will not come up to proper pressure with minimum shims, they must be replaced.

HEAD ASSEMBLY

Now everything is ready for assembly of the head. The valves are replaced in their respective guides one by one. The oil seal is inserted over each stem, followed by the spring and shims if necessary. With the big C-clamp, the spring is again depressed and the retainer washer and keepers are reinstalled. The head(s) are then ready to be installed on the cylinder block.

FINAL ASSEMBLY

Unless the camshaft has been changed to a high-lift version, or the piston head design is different, there is usually no need to check piston-to-valve clearance. However, if such a change has been made, this check is imperative, for flathead as well as ohv engines.

To check this clearance, lay thin strips of modeling clay atop the piston for ohv engines, and over the valves for flathead engines. Bolt on the head, using the old headgasket, and torque it to the correct specification. All the valve mechanism must be included. Rotate the engine several times, then remove the head(s). If the clay measures less than .060-in. where it has been pressed between valve and piston or valve and head, more clearance will be necessary. In case of the overhead engine, the clearance must be flycut into the piston or the valve set deeper in the seat (which is not recommended). For the flathead engine, the head chamber above the valves must be flycut the necessary amount.

If the camshaft or piston design has not been modified, there will be no need for this clearance check, provided all stock replacement parts have been used. The head gasket should be installed as marked, with the indicated top and front portion so placed, if necessary. Sealing compound or aluminum paint may be used on both gasket surfaces, and the gasket prescribed for the engine should absolutely be used. In case a thin high-compression replacement gasket is involved, then the valve-to-head or valve-to-piston clearance will need to be checked.

All headbolts should be inspected before reuse, and any slight distortion means the bolt should be replaced. Coat the threads with an anti-seize compound, then torque the bolts to the prescribed pounds and in the torque pattern established by the engine manufacturer. This pattern usually starts in the middle of the head and works toward either end. It is imperative that the proper torque pattern and pound limits be followed to minimize block and head distortion!

The lifters may be placed in the respective bores before the head is installed (remember, they go back to the same hole they came from), and so may the pushrods. However, the pushrods must be in the rocker arm pivots before any of the headbolts are tightened in place.

The valley cover may be replaced now. Since this is separate from the intake manifold on most modern V-8's, it should have sealing compound included on both sides of the gasket. Also, if small rubber seals are involved around the central hold-down bolt(s), new seals should be included. Nothing is more discouraging than to have an oil leak around these bolt seals after the engine is assembled and back in the car.

MANIFOLDS, INTAKE AND EXHAUST

When the head was being checked for a warped condition, one of the surfaces involved was the manifold flat, for both intake and exhaust manifolds. Naturally,

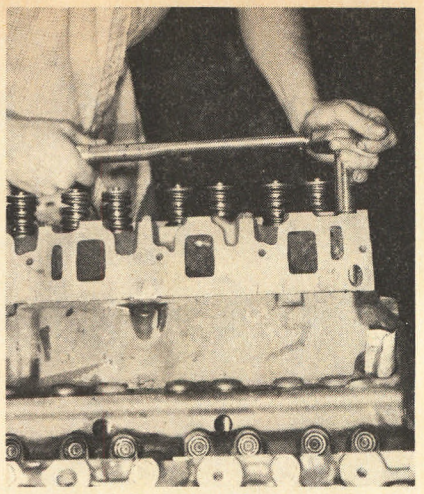
1. Pre-assembled head is bolted in place and torqued to factory specs.

2. Rocker arm shaft assembly and new pushrods are installed, then head bolts are tightened.

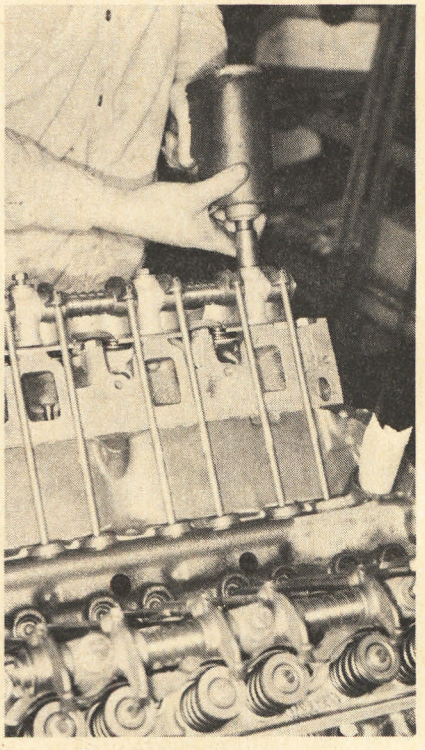
3. Clearance in the hydraulic lifter is checked. If clearance is not sufficient, a shorter pushrod is used; if clearance is too much, a longer one is substituted.

4. Engine is positioned on a run-in stand and coupled to an electric motor that turns the engine over at a constant speed.

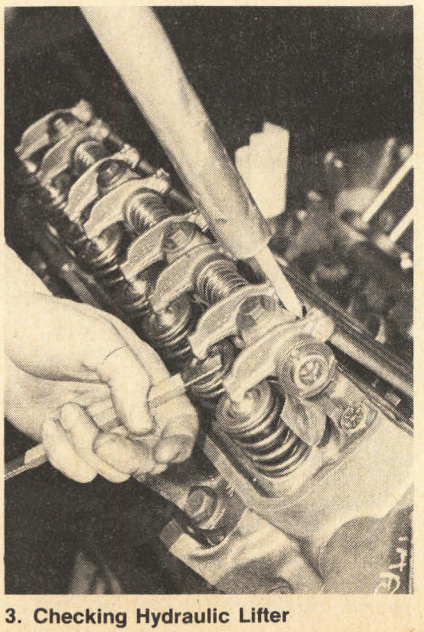
5. Compression testing of each cylinder and check of oil pressure completes rebuild. Engine is now ready for painting and sealing in plastic prior to delivery.



1. Torquing Cylinder Head



2. Installing Rocker Arms



3. Checking Hydraulic Lifter

this same check must be given the manifolds, and they must be trued up by grinding, if necessary.

There is not much that can go wrong with the manifold, but if it is cracked the break must be repaired. This can be done by welding or brazing, the latter most common, and is acceptable on both intake and exhaust systems. After welding, the manifold should be heated to relieve any stress concentrations, and the mating surfaces machined true.

The manifolds must be cleaned of any carbon buildup, then assembled to the engine with torque specifications observed. A sealing compound may be desirable around the intake gaskets. The spark plugs are then torqued to the heads, and exhaust/intake opening taped shut. This will prevent any loose "goodie" from falling inside and undoing all the hard work you've just completed.

Valve covers may be installed at this time, but no sealing compound will be necessary as they utilize thick, soft gaskets. Make sure all the block plugs and fittings are in place and the assembly should be complete. All that remains is to hang on the accessories, and you may want to do that after the engine is in the car, to prevent damage to them during the installation.

PREVENTING DRY STARTS

An engine can wear more in the first 30 secs. after it is started up than in the next 6 months if it has a prolonged dry start. Special lubes are available for coating the camshaft lobes to prevent galling. Every other part in the engine should have been assembled with liberal amounts of engine oil. It's good practice to pack the oil pump with Vaseline when it is assembled. A pump primed with Vaseline will start circulating oil almost instantly, whereas one that has to start dry may take several seconds before it can suck oil up from the pan and distribute it through the engine oiling system.

Some engine builders prime the oil pump by driving a dummy distributor with a drill motor. The distributor must have the gear removed so that it does not try to turn the camshaft. The drill motor is chucked onto the top of the distributor shaft, and the tang at the bottom end of the shaft will drive the oil pump just as if the distributor were being run in the engine. It only takes a few seconds of drill motor operation to get complete oil pressure even to the point where it starts squirting out of the rocker arms. Drill motors rotate clockwise, so this technique can only be used on those engines with distributors that also rotate clockwise. If you turn the dummy distributor and the oil pump in the wrong direction, you won't hurt anything but you won't be pumping any oil either. You'll just be blowing bubbles down into the oil in the pan.

A reversible drill motor will work on any engine, but all of the problems with figuring out how to do this can be avoided in the first place simply by packing the oil pump with Vaseline. As soon as the engine oil gets warm the Vaseline melts, and then dilutes to the point where it never congeals thereafter.

ENGINE TIMING

Setting valve lash and timing the distributor are where many amateur mechanics fall down. They may have assembled a very good engine, only to have things unravel in either or both of these categories.

To time an engine, rotate the crankshaft until the No. 1 piston is on top dead center (TDC) of the compression stroke. Move the crank back and forth a few degrees either way and watch the No. 1 rocker arms. If they move, the engine is on the exhaust stroke and must be rotated again. With the piston on TDC of the compression stroke, the timing marks on the crankshaft pulley should be aligned with the timing pointer attached to the timing cover.

Now install the distributor with the rotor pointing directly to the No. 1 distributor cap terminal (the secondary, or ignition wires were taped, remember?). Adjust the distributor by turning it in the direction of rotation until the distributor points just barely begin to open. In this way, a very slight lead is involved and the engine will start. Final distributor adjustment is then made with the use of a timing light.

It is common for amateurs to get the ignition installed to fire on the exhaust stroke, and this leads to all kinds of frustration. If the engine does not start right away, recheck to see that the distributor is not out of phase with the cylinders.

Setting valve lash is not difficult, but is often accomplished in a most rough-shod manner. Hydraulic lifters require no lash adjustment per se, but some engines call for one turn adjustment from zero lash. This places the lifter plunger in the center of the housing travel. To make this kind of adjustment, loosen the rocker adjustment stud until the valve clatters, then tighten it to zero-lash, or when the valve is quiet (this is a close point, so listen carefully). Now tighten the adjustment screw by one additional full turn; make the adjustment ¼-turn at a time to allow the lifter to bleed down. Some engines have different length pushrods for adjustment.

Adjustment of the solid lifter is made with a feeler gauge and requires nothing more special than patience. The lifter must be on the heel of the cam for this adjustment; that is, the valves must be fully closed. Turn the adjusting screw in the rocker until the feeler is a snug but removable fit, and tighten the locknut. Until proficient in adjusting mechanical lifters, the mechanic should recheck the initial cold settings after the engine has warmed up (the settings are different and are called out in the shop manuals).

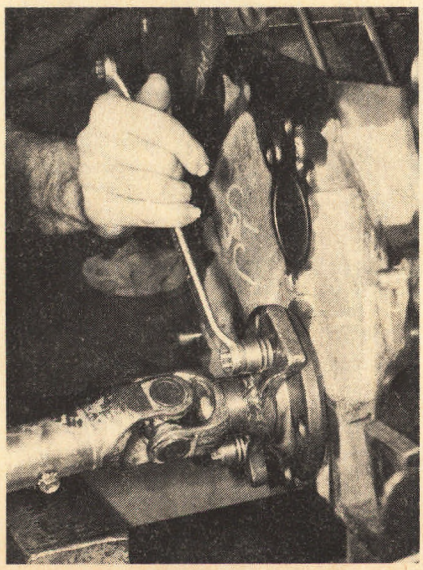
ENGINE BREAK-IN

How an overhauled engine is broken in will determine how well it runs. As soon as it is started, it should be set at an rpm equivalent to 20-30 mph, or slightly over 1000 rpm. This allows the oil to circulate through the engine galleries well, and throws oil onto the cylinder walls.

As a rule, don't let the engine idle, and don't operate it with cold water running through the block. So that takes care of the idea of letting the engine break-in with a garden hose stuck in the radiator. The engine must reach operating temperature for the rings to seat, and the closer to the boiling point the better, although it shouldn't be allowed to boil.

After the engine has run awhile, drive it around to get everything loosened up. This will be but a few miles. Then retorque the head and manifold bolts and reset the valve adjustment with solid lifters. The ignition timing should be rechecked, and the carburetor adjusted for correct idle speed.

To seat the rings, accelerate the car at full throttle briefly from 30 mph. This will load the rings and cause the slight wear necessary. Hard rings will take slightly longer to seat. Drive the car under 50 mph for the first 250 miles, and at no sustained high speeds for the first 1000 miles. Drain the oil and change the filter at 1000 miles and then observe regular lubrication maintenance.



4. Engine on Run-in Stand

5. Final Test Before Painting

ENGINE NOISES

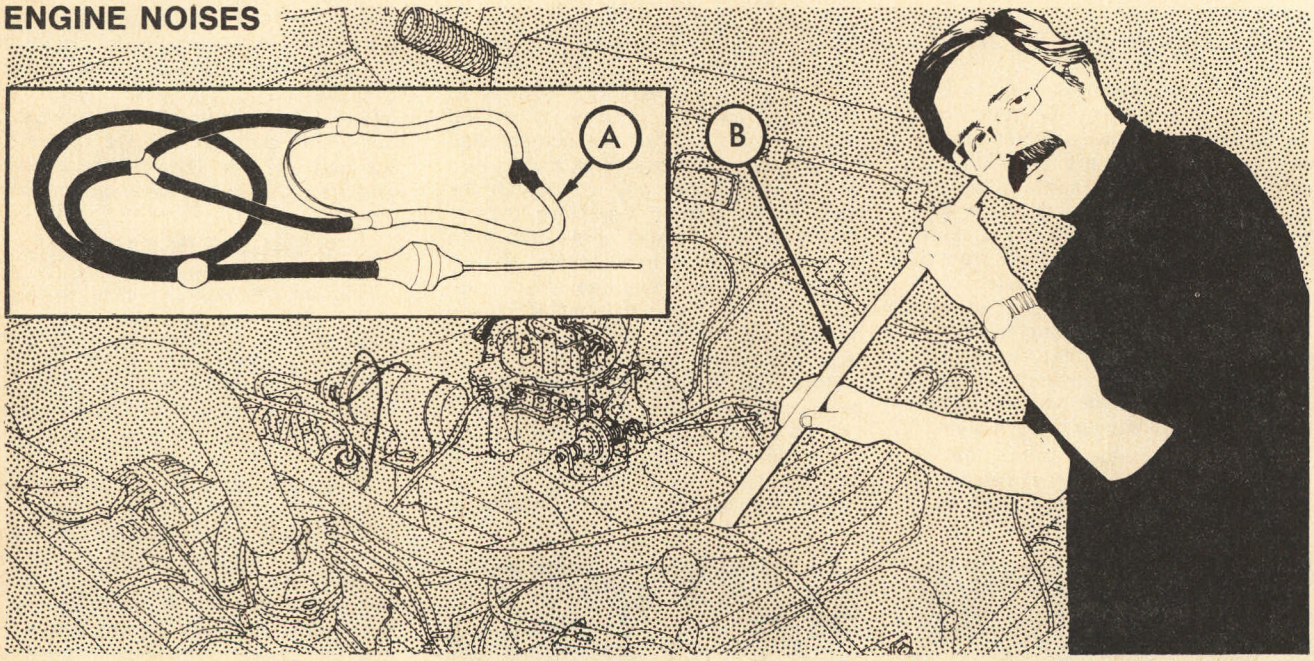
ENGINE TROUBLESHOOTING

This section deals with internal engine problems that may not be reflected in the three logic trees on starting, ignition and fuel systems. Many of the components of an engine are checked by professional mechanics with sophisticated test equipment and special tools. This book will limit its coverage of troubleshooting methods to those that can reasonably be expected to be done with simple tools by the home mechanic or student mechanic. In cases where the use of more specialized tools is required, we direct the reader to other sources, such as manufacturer's shop manuals, for more complete information concerning the use of these tools.

The modern internal combustion engine is highly reliable as long as it is kept in decent operating condition through preventive maintenance. With proper cooling, required lubrication, good fuel and tune-ups and adjustments at the required intervals, the engine will usually last for many years without major problems. Many of the faults discussed in this chapter apply to engines that have been in service over long periods of time rather than problems of a minor nature that can occur at any time.

When troubleshooting an engine, *check the obvious first!* Look for signs of mechanical problems such as loose or broken components, oil, water or fuel leaks in the engine or on the ground beneath the engine. The first section of this chapter on engine troubleshooting deals with just such a method of troubleshooting: using your ears to detect engine malfunctions.

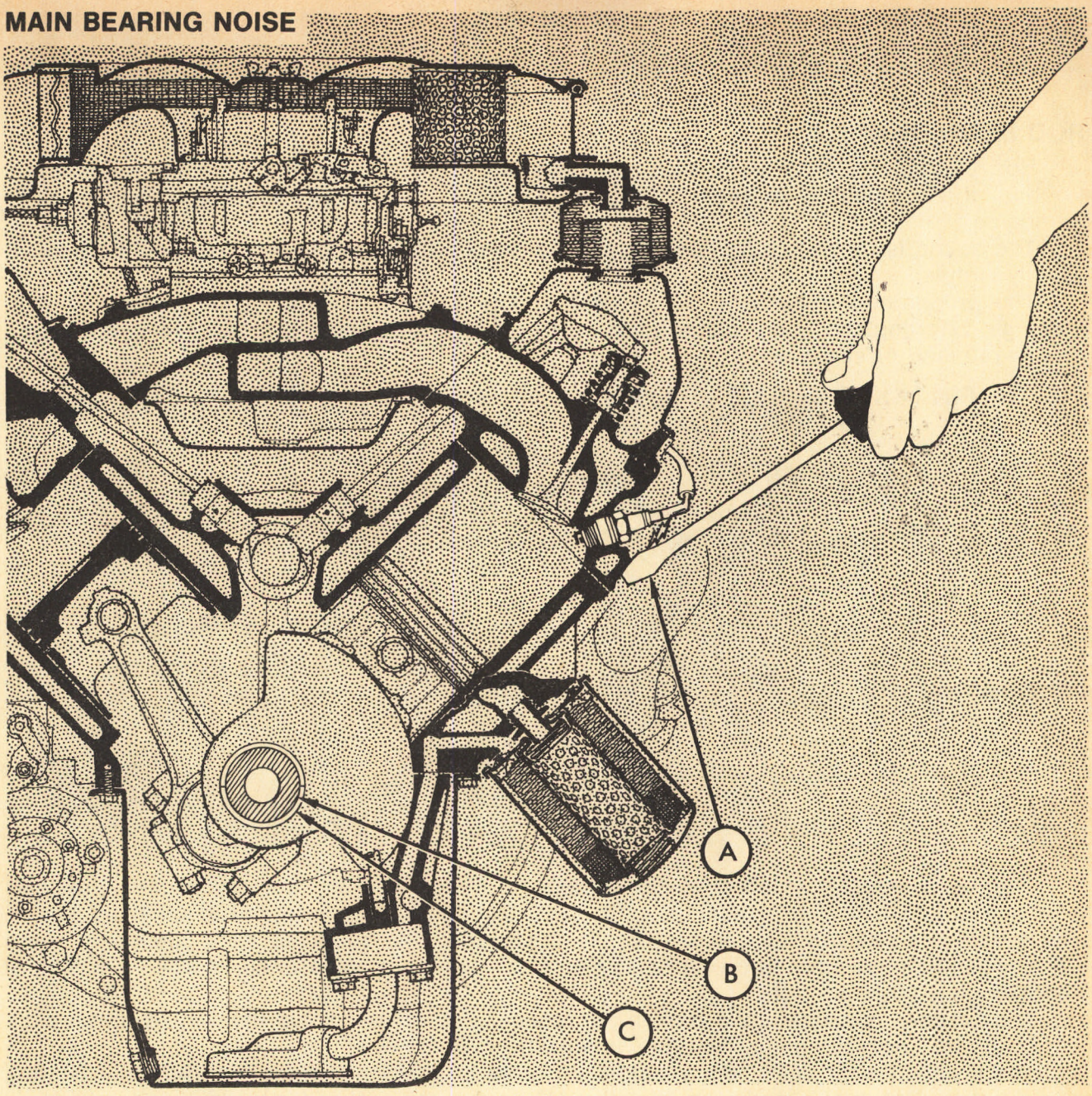
ENGINE NOISES



Engine noises are a good indicator of problem areas. Often a malfunction inside the engine will reveal itself first as a strange sound, before the effects of the problem become apparent in any other manner. There is, however, a drawback to using engine noises to troubleshoot. Unless you have some experience in listening to the various sounds that an engine can make, sometimes it's hard to determine just what you are listening to and exactly where it is coming from.

One simple tool which will aid the troubleshooter attempting to find a problem is a sounding stick (B) or mechanic's stethoscope (A). A sounding stick may be a piece of broom handle or a hollow tube. The sounding stick works by slightly dampening the sound around it while permitting the troubleshooter to hear a particular sound easily. The stick should be placed on the engine in the desired location, then the ear or the side of the head should be touched to the stick to listen to the sounds coming from inside the engine. Moving the stick from place to place on the engine will help to isolate the location of the sound that you are interested in. The mechanic's stethoscope works on exactly the same principle, but is capable of giving clearer results.

MAIN BEARING NOISE



The engine main bearings (B) are bearings which fasten around the crankshaft (C) to support it inside the engine block. A problem in this area is accompanied by a strong, dull knocking or thudding sound, especially when the engine is under a load (going uphill). If more than one of the bearings is developing a problem, the sound will be a steady clatter.

The cause of main bearing noise is either a lack of lubrication or a bearing that has been worn to such a degree that insufficient lubrication is reaching the bearing surfaces.

This problem should not be allowed to persist. Main bearing failure can result in severe engine damage, so the engine should not be run any longer than it takes to confirm the source of the noise.

Main bearing noise or "knock" can be narrowed down to an individual bearing by shorting out spark plugs on cylinders adjacent to the bearing. Unless your ignition system wiring has a full rubber cover insulating the entire tip of the spark plug, it is fairly easy to short out the plug with a long-bladed screwdriver (A).

When the cylinder closest to the main bearing that is making the noise is shorted, it kills the power stroke and reduces the driving force transmitted to the crankshaft. This lessens the load being put on the faulty bearing, and the noise decreases or disappears.

Once it has been determined that the main bearing(s) are knocking, repairing them requires complete disassembly of the engine for an overhaul. Consult the manufacturer's shop manual for engine disassembly instructions. (Also see Petersen's COMPLETE BOOK OF ENGINES.)

ENGINE NOISES

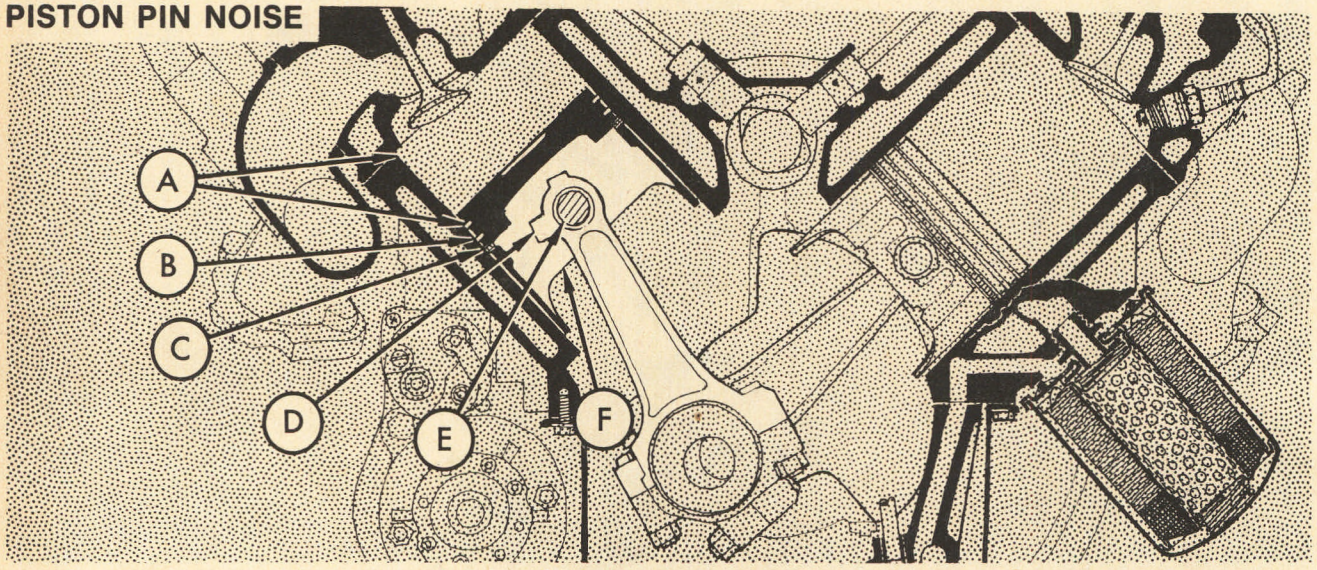
ROD BEARING NOISE

Rod bearing noise is much like main bearing noise and comes from the same basic troubles. If a rod bearing problem is allowed to persist, it can cause considerable damage to an engine.

The sound is much like a main bearing, but is slightly more metallic and may be pitched slightly higher.

The procedure for isolating a rod bearing knock is exactly the same as for the main bearings. Shorting the spark plugs adjacent to the bad bearing will cause the sound to be greatly reduced or eliminated.

PISTON PIN NOISE



The piston pin (E), which connects the piston (F) to the top of the rod, makes a metallic knocking sound which is sometimes difficult to distinguish from the sound of a rod knock. The sound is a sharp double knock or clicking sound. The sound is most commonly heard when the engine is idling, but it can also be heard clearly on some engines when traveling at approximately 25 to 35 mph.

The problem is caused by a broken pin retainer (D), which allows the pin to move back and forth and come in contact with the side of the cylinder wall.

The procedure for determining piston pin noise is the same as for rod and main bearing noise, but the result is exactly the opposite. When the spark plug for the affected cylinder is shorted, the sound will increase instead of decrease. This is a good way to tell the difference between piston pin noise and that of rod or main bearing noises. In the case of multiple piston pin noise, it may be difficult to tell the difference between this and several other internal noises.

Some other piston-associated noises are:

1. Broken piston (E).

2. Broken piston ring (C).

3. Top piston ring strikes ridge at top of cylinder (A).

4. Piston slap (too much clearance between piston and cylinder wall). This is most common when the engine is cold.

5. Excessive side clearance of the ring in the piston lands (B). Lands are the retaining grooves machined in the sides of the pistons to hold the piston rings.

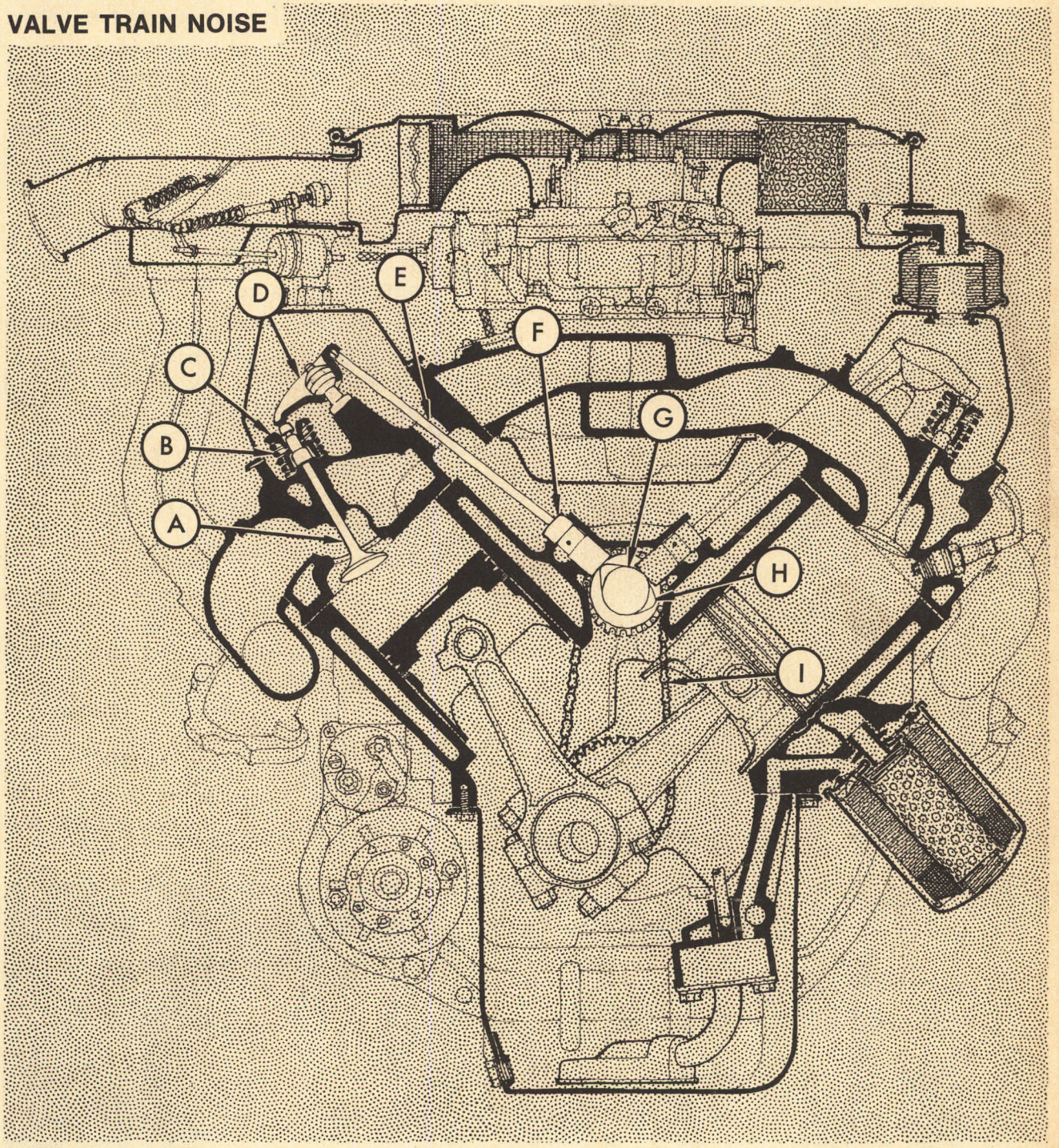
6. Carbon deposit on top of the piston, which will strike the cylinder head at the top of the piston's stroke.

7. Out-of-round or tapered cylinder bore. (This is due to wear that causes the material of the cylinder to be ground away.)

Any or all of these additional sources of noise may account for piston noises, but all mean the same thing. An engine which is making considerable noise is probably in need of an overhaul or replacement of parts such as bearings, rings, etc.

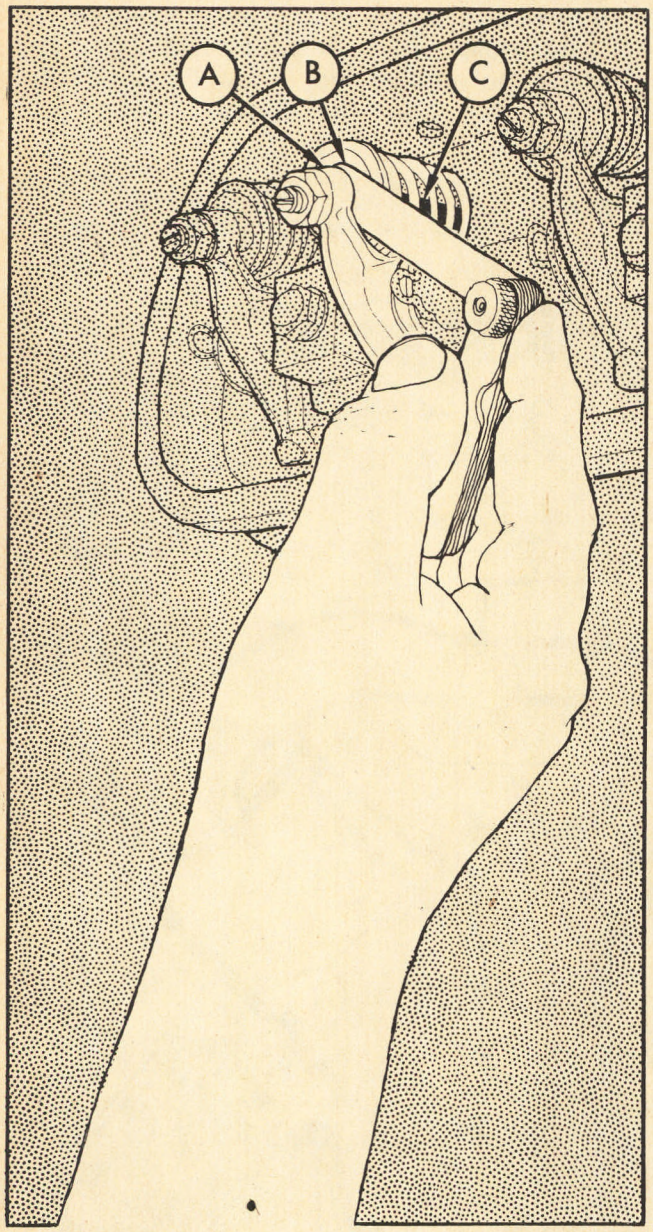
One additional check to isolate piston noises to a single cylinder or determine if the sound you hear is really a piston problem is to remove the spark plug from the suspected cylinder and squirt some heavy oil into the spark plug hole. This will briefly seal bad rings and provide lubrication. After squirting in the oil, crank the engine over a few times with the ignition disabled (coil high-tension lead disconnected), then start the engine. The cylinder that has been oiled should remain quiet for several minutes.

VALVE TRAIN NOISE



The valve train in the modern automobile engine includes the valves (A), springs (B), retainers (C), rocker arm (D), pushrods (E), tappets (lifters) (F) and the cam (G), which actuates the valve train. The cam is connected to the crankshaft by a chain drive (I) or belt drive in some late-model overhead cam engines. The cam rotates at half the engine speed. As the cam rotates, the eccentric cam lobes (H) push against the tappets, moving them up and down. This up and down action is transmitted through the rest of the valve train (pushrods and rocker arms) to open and close the valves in the correct sequence.

ENGINE NOISES



The most common cause of valve train noise is excessive clearance between components. Adjustment to the correct clearance is a job that is usually done during routine tune-ups. It is likely that if your car is making slight noises from the valve area, the valves are out of adjustment.

The sound of out-of-adjustment valves is a regular clicking sound. Since the valves are operated at half the engine speed, the frequency of the clicking noise will generally be less than other noises.

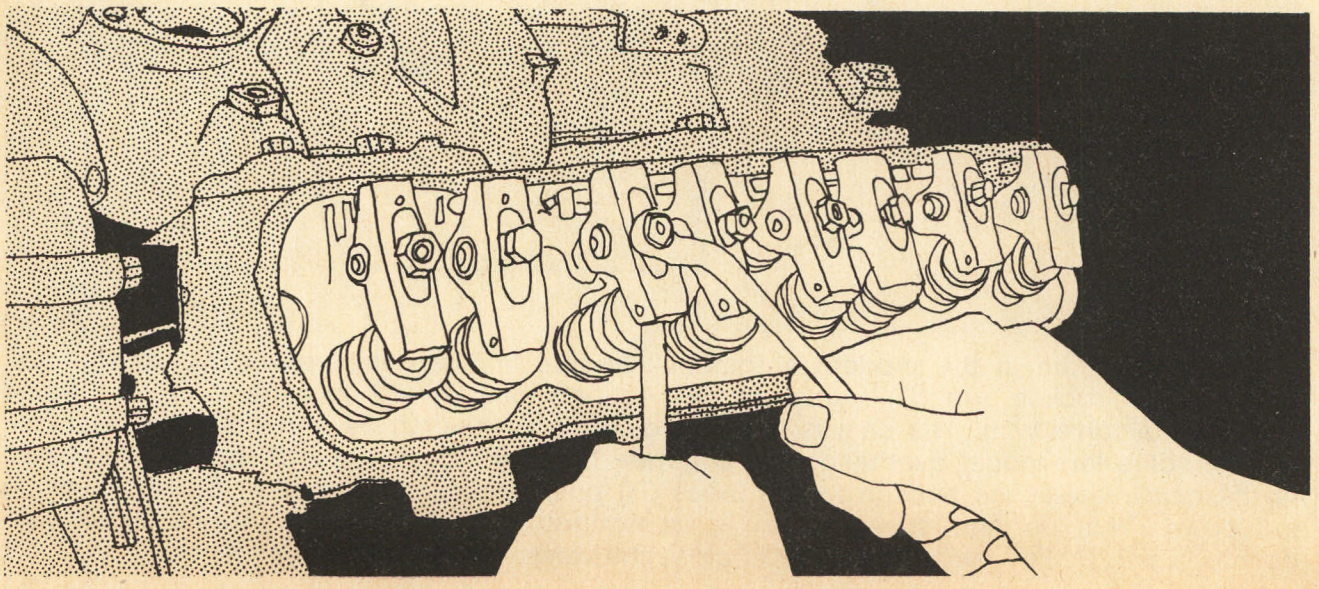
Locating a noisy valve with excessive clearance is easy; the only tool required is a feeler gauge (C). Remove the valve cover from the engine and start the engine.

> **NOTE:** REFER TO A SHOP MANUAL FOR INFORMATION ON VALVE COVER REMOVAL AND THE REMOVAL OF ACCESSORIES BEFORE THE VALVE COVER CAN BE REMOVED. ALSO CHECK YOUR OWNER'S MANUAL OR SHOP MANUAL FOR THE CORRECT VALVE CLEARANCE SPECIFICATION FOR YOUR CAR.

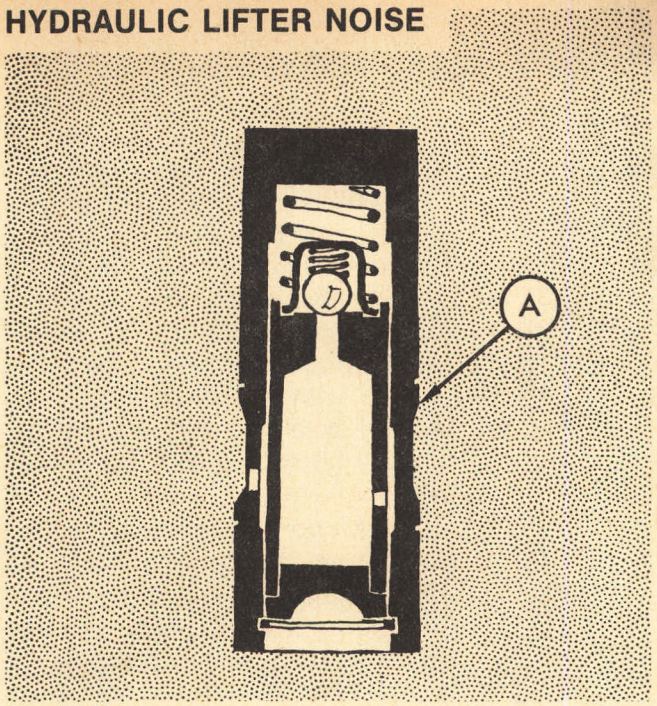
With the engine running, select the correct size feeler gauge blade and insert it between the valve stem (B) and rocker arm (A).

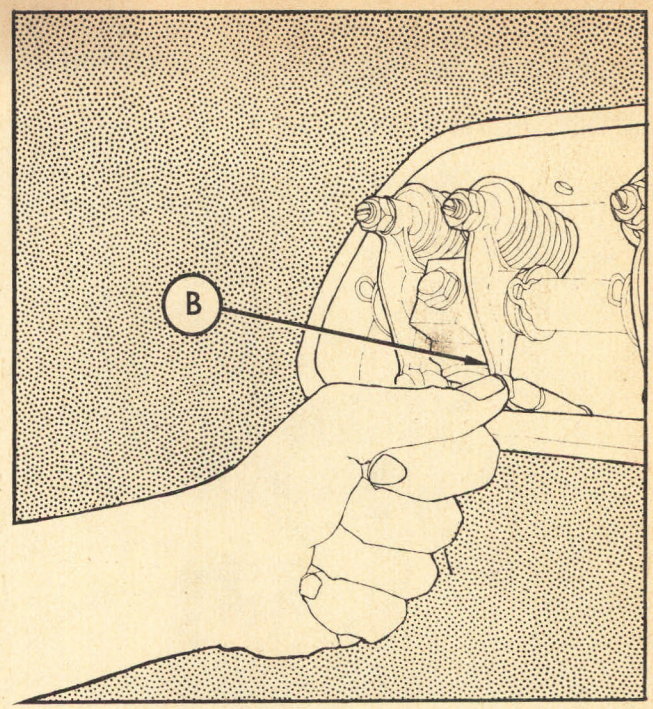
If the problem is excessive clearance, the insertion of the feeler gauge will quiet the sound of the valve train for that valve.

To adjust the valve, refer to the shop manual or your owner's manual. (Also see Petersen's HOW TO TUNE YOUR CAR.)



HYDRAULIC LIFTER NOISE





The hydraulic lifter (tappet) (A) is designed to cushion the opening and closing of the valve and reduce the shock to the valve train by the use of oil as a self-adjusting device. These hydraulic lifters frequently become noisy. The most common cause is either lack of oil or dirt plugging the oil holes in the body of the lifter, preventing it from working properly.

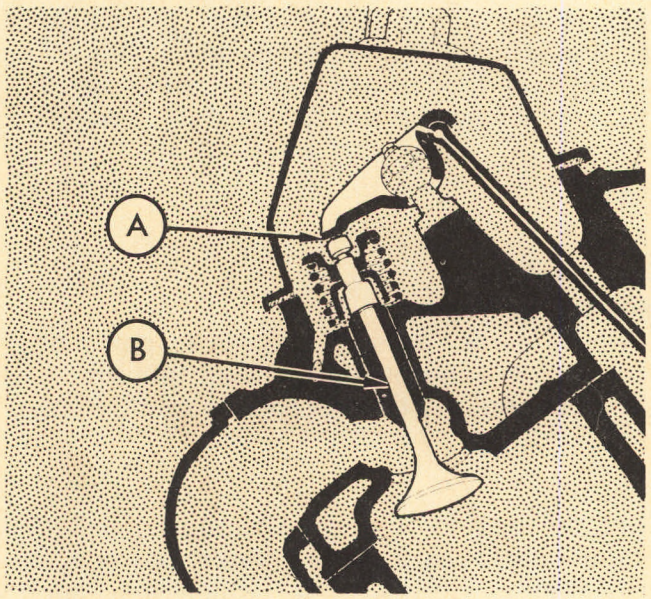
1. To locate a suspected noisy hydraulic lifter, remove the valve cover and start the engine.

2. Place a finger on each rocker arm (B) in turn (with the engine idling).

3. If the hydraulic lifter is not functioning properly, you will feel a sharp and distinct shock (not an electrical shock) as the valve returns to its seat.

4. To adjust the hydraulic lifter, refer to the shop manual or your owner's manual for instructions.

STICKING VALVE NOISE



A valve which is sticking during its travel will make a noise very similar to that of a badly-adjusted valve (B).

To check for suspected sticky valves, drive the car at high speed, then quickly stop and allow the car to idle.

If there is a sticky valve, the clicking sound will be quite loud, but will gradually grow quieter and in some cases disappear completely as the engine cools down.

NOTE: THE NOISE MAY ALSO BE ACCOMPANIED BY A JERKY OR ERRATIC ENGINE IDLE. WHEN RUNNING THE TEST JUST DESCRIBED, THE ERRATIC IDLE SHOULD DISAPPEAR ALONG WITH THE NOISE.

Some other valve-train-associated noises are caused by:

1. Insufficient oil reaching the valve components.

2. Worn or scored parts anywhere in the valve train.

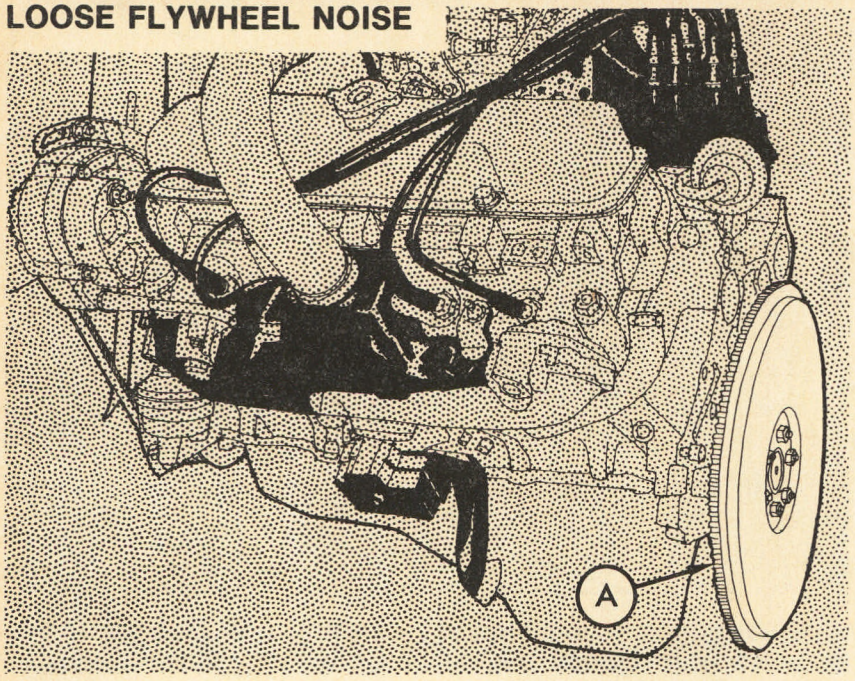
3. Weak or broken valve springs.

4. Lower end of the tappet becoming rough, chipped, worn or broken.

5. Excessive valve stem to valve guide clearance (A).

ENGINE NOISES

LOOSE FLYWHEEL NOISE



The heavy flywheel (A) attached to the back of the crankshaft on standard transmission-equipped cars can cause a strong clicking sound if it becomes loose. The sound is usually intermittent. To check for a loose flywheel, start the engine with the transmission in neutral and run the engine up to approximately 20 mph (simulated).

Turn off the ignition switch, and when the engine has just about stopped, turn the switch on again. This process should be repeated several times. If the flywheel is loose, you should hear the clicking sound each time the switch is turned on.

EXCESSIVE CRANKSHAFT ENDPLAY NOISE

Excessive crankshaft endplay (fore and aft movement) will cause a sharp click or rap which is quite easy to hear.

To check this, run the engine at idle speeds with transmission in neutral. Engage and disengage the clutch several times. The sharp click or rap should be heard during engagement of the clutch.

PRE-IGNITION NOISE

Pre-ignition noise, commonly called "ping," is a ringing metallic sound usually heard when the engine accelerates strongly (quick takeoff or climbing a hill) or is hot. One cause is an incandescent (glowing with intense heat) particle of carbon or metal in the combustion chamber which ignites the air/fuel mixture before it is fired by the spark. Because this happens while the piston is still moving up and compressing the air/fuel mixture, very high pressures are built up in the cylinder.

Other causes of pre-ignition are:

1. Ignition timing that's advanced too far.
2. Using gas with too low an octane rating for your engine.
3. Transmission in wrong gear, causing the engine to lug down.

The method of correcting pre-ignition ping where carbon is suspected is to partly disassemble the engine (remove the cylinder heads) and remove the built-up carbon from the tops of the pistons and the insides of the combustion chambers. (For more complete information, refer to a shop manual.)

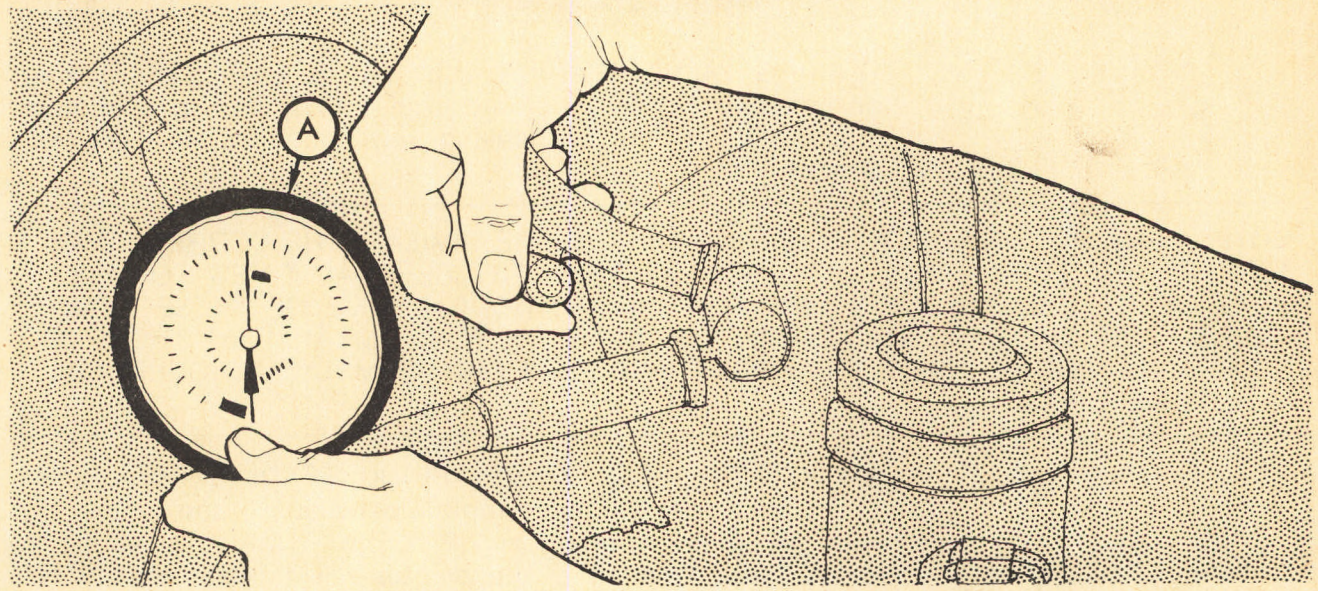
EXTERNAL ENGINE EQUIPMENT NOISES

All of the accessory equipment associated with the engine can cause strange noises that worry the driver. Generators, alternators, air conditioning pumps, water pumps, power steering and brake equipment—each can make a number of noises, all of which may sound basically the same to the person trying to troubleshoot the source of a strange noise under the hood of his car.

Each of these individual parts can be isolated by disconnecting it from the engine. For example: A squeaky sound which seems to be coming from the auto's air conditioning pump can be checked by loosening the drive belt so that the pump does not operate when the engine is running. If the sound goes away, chances are that you have found the general area of the problem. You can then refer to the specific part of this book or other references for more information on fixing the problem part.

TROUBLESHOOTING WITH A VACUUM GAUGE

TROUBLESHOOTING WITH A VACUUM GAUGE

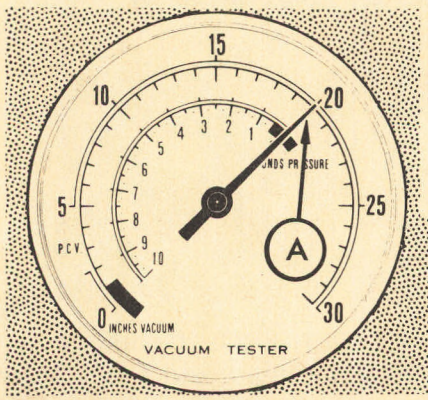


One of the most practical methods of determining the internal condition of an engine is through the use of a vacuum gauge (A). The internal vacuum of the engine varies with each separate operation of its parts. The gauge itself is not expensive, and the information gained from it is very valuable in troubleshooting.

The vacuum gauge reads the level of vacuum built up in the intake manifold while the engine is running. Several parts of the automobile operate off this vacuum, such as windshield wipers (in some models), power brakes and distributor vacuum advance. By means of a hose and fitting, the vacuum gauge connects to the intake manifold or between the manifold and one of the accessories that uses its vacuum to function. Instructions packed with the vacuum gauge or in the shop manual for the car you are working on will give the exact hookup procedure.

The vacuum gauge reads internal engine vacuum in inches of mercury. Inches-of-mercury is abbreviated "ins. Hg", and that's how we will write it in this section. Ins. Hg is a measurement developed by placing liquid mercury in a glass tube and marking the tube off in divisions. A vacuum applied to one end of the tube causes the mercury to rise or fall in the tube a specific distance, a measurement that can be used to rate the strength of any vacuum or change in pressure. A barometer works on this same principle. You don't have to worry about the principles involved; the meter or dial of the vacuum is clearly marked and easy to read. This inexpensive tool is very valuable for both professional and home mechanics.

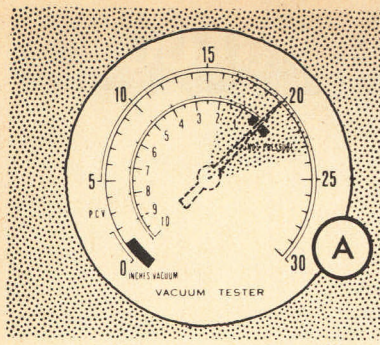
VACUUM GAUGE TROUBLESHOOTING LIST



NORMAL ENGINE READING: A normal engine will produce a gauge reading (A) of approximately 18 to 22 ins. Hg with the pointer remaining quite steady.

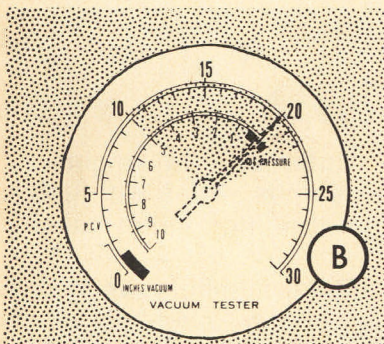
Eight-cylinder engines will read toward the high end of the scale, while six-cylinder engines will read toward the low end of the scale.

NOTE: SOME LATE MODEL CARS WITH OVERLAPPING VALVE TIMING MAY SHOW A CERTAIN AMOUNT OF NEEDLE MOVEMENT.

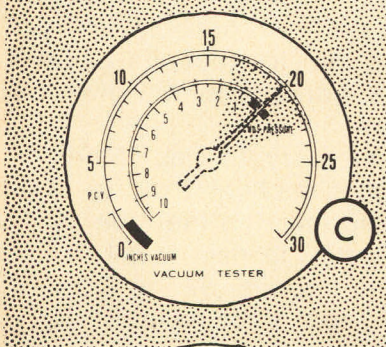


LEAKING VALVE READING: If a valve is leaking, the pointer on indicator (A) will fluctuate from 1 to 7 ins. Hg at regular intervals each time the leaking valve attempts to close (engine at idle).

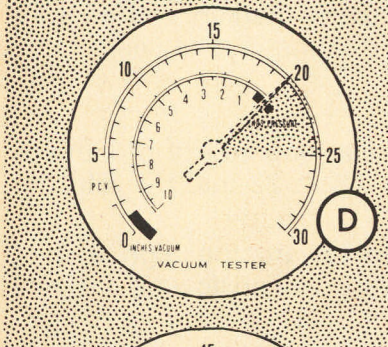
NOTE: MANY OF THE INDICATIONS SHOWN HERE ARE SIMILAR. THE CORRECT WAY TO PERFORM THIS CHECK IS TO REPEAT THE TEST SEVERAL TIMES TO MAKE SURE OF THE READINGS YOU ARE GETTING. ALTHOUGH SOME OF THESE READINGS MAY BE THE SAME OR NEARLY THE SAME, THEY ALL MEAN THAT THERE IS SOMETHING WRONG INSIDE THE ENGINE AND THAT DISASSEMBLY AND OVERHAUL MAY BE NEEDED.



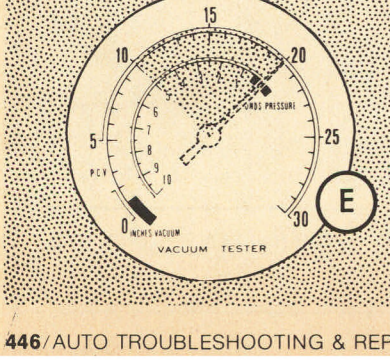
BROKEN OR WEAK VALVE SPRING READING: The pointer on indicator (B) will move rapidly between 10 and 22 ins. Hg with the engine running at 2,000 rpm. If the valve spring is weak, the movement of the pointer will increase as the engine rpm increase. If the valve spring is broken, the pointer will move rapidly each time the valve attempts to close.



WORN VALVE GUIDES READING: Valve guides (portions of the cylinder head through which the stems of the intake and exhaust valves pass) will give a reading on indicator (C) lower than normal, with slow fluctuations of approximately 3 ins. Hg above and below normal when the engine is at idle.

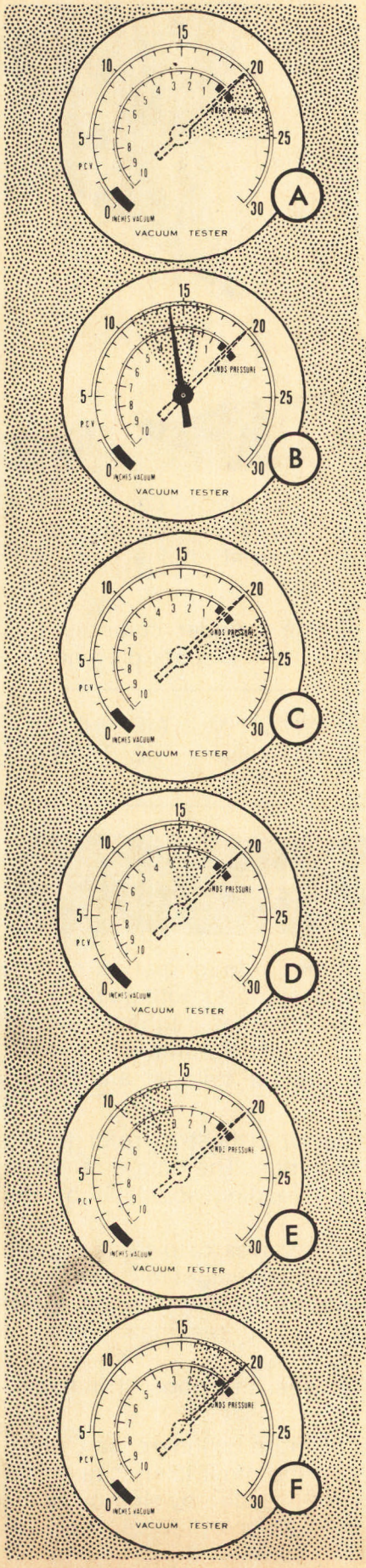


PISTON RING DEFECTS READING: Bring the engine speed to approximately 2,000 rpm, then release the throttle quickly. The pointer on indicator (D) should jump from approximately 2 ins. Hg to 5 ins. Hg above the normal reading if the rings are good. A lower reading should be followed up by making a compression check.



BLOWN CYLINDER HEAD GASKET READING: If some portion of the gasket between the cylinder head and the block has failed and is letting the engine compression leak from one or more cylinders, the pointer on indicator (E) will drop sharply to approximately 10 ins. Hg each time the affected cylinder(s) fire(s).

TROUBLESHOOTING WITH A VACUUM GAUGE



INCORRECT IDLE AIR/FUEL MIXTURE READING: If the needle on indicator (A) drifts slowly back and forth above the normal reading when the engine is idling, the fuel mixture is too rich (too much gas for the amount of air entering the engine). A lean mixture (too little fuel) will cause the pointer to drop slightly at irregular intervals.

INTAKE MANIFOLD AIR LEAKS READING: If there is any air leaking between the intake manifold and the cylinder heads, the pointer on indicator (B) will drop from 3 ins. Hg to 9 ins. Hg below the normal engine reading (engine at idle) and will remain quite steady.

EXHAUST SYSTEM RESTRICTION READING: If there is something causing a restriction (back pressure) in the exhaust system, it can seriously affect engine performance. To check this, open the throttle until the engine reaches approximately 2,000 rpm. Then release the throttle quickly. If there is no restriction, the pointer on indicator (C) will drop to not less than 2 ins. Hg or more above the normal engine reading. If the gauge does not show 5 ins. Hg or more above the normal reading and the pointer seems to stop for a moment as it returns, the exhaust system is partially restricted. Check for bent or dented exhaust pipes or a core shift inside the muffler.

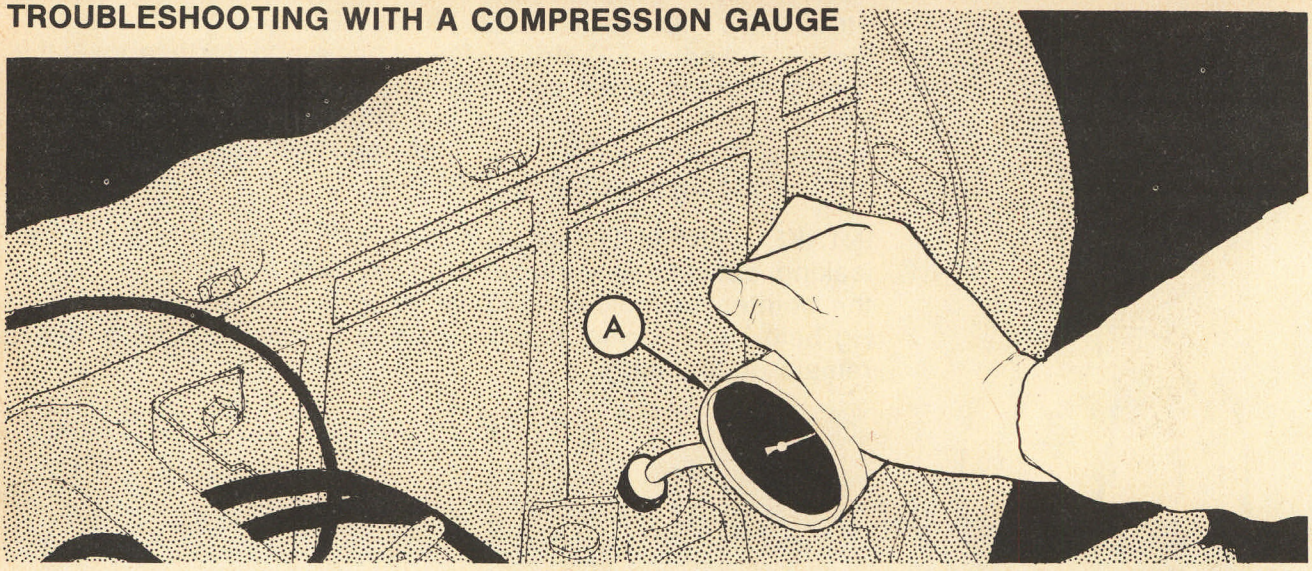
LATE IGNITION TIMING READING: A low, steady reading on indicator (D) at idle indicates late ignition timing (retarded) or that the valve clearances are too tight.

LATE VALVE TIMING READING: A steady but very low reading on indicator (E) is generally caused by late ignition timing. But if advancing the ignition timing does not increase the reading, the valve timing is out of adjustment.

STICKING VALVE READING: A sticking valve is indicated on gauge (F) by a rapid, intermittent pointer drop every time the valve is supposed to close while the engine is at idle. A sticking valve condition can be pinpointed by applying a small amount of penetrating oil or lacquer thinner to each valve guide in turn. When you reach the sticky valve, the problem will clear up for a few minutes.

TROUBLESHOOTING WITH COMPRESSION GAUGE

TROUBLESHOOTING WITH A COMPRESSION GAUGE



The compression gauge (A) is used to check the ability of each cylinder to compress the air/fuel mixture for burning. It is an important tool for troubleshooting. Along with the vacuum gauge, it can tell the mechanic about a number of important internal engine parts and how they are working.

USING THE GAUGE: To use a compression gauge to check engine cylinder compression, remove all the spark plugs. Insert the tip of the compression gauge into the spark plug hole.

NOTE: SOME COMPRESSION GAUGES HAVE A RUBBER TIP WHICH MUST BE HELD IN PLACE, WHILE OTHERS USE A THREADED TIP WHICH SCREWS INTO THE SPARK PLUG HOLE.

CAUTION: BE SURE TO DISCONNECT THE COIL HIGH-TENSION LEAD BEFORE CRANKING THE ENGINE.

With the throttle held wide open, crank the engine over for a long enough period of time to record several complete revolutions of the engine. Most good compression gauges are equipped with a device that traps the air inside the gauge so that the highest reading obtained will stay on the face of the indicator (by the use of a dual pointer) until you release it. Note the reading on the indicator (write it down), then go to another cylinder and repeat until you have checked all the cylinders.

CHECKING THE RESULTS: Because all engines are not identical, it is best to refer to the shop manual for the engine you are working on for the correct readings. The gauge readings should be within 10 pounds above or below (± 10 pounds) the reading specified by the manufacturer.

Readings *below* the listed specifications indicate that the rings, valves or pistons require maintenance. You can further check this by squirting some medium-weight oil into each spark plug opening. Work the oil down into the rings by cranking the engine over for a few seconds, then repeat the checks with the compression gauge. If the readings come up normal, the problem is the rings, pistons or cylinder.

If there is no increase in the readings as the oil attempts to seal the rings, it indicates that the valves are in poor condition.

BLOWN HEAD GASKETS: A serious drop in pressure in one or more cylinders can mean several things, from broken rings to a hole burned in a piston, but the most likely cause is a blown head gasket. Another strong sign of a blown head gasket is two side-by-side cylinders that show approximately the same low compression reading while other cylinders check as good. This indicates that the head gasket is blown (torn or broken) between the cylinders.

Engine Overhaul Checklist

Whether you're ready to tackle all or just part of an engine overhaul—or prefer to let a professional do the job—this handy checklist covers the major parts needed to rebuild a stock automotive piston engine and the necessary machine work to do it properly.

When used in conjunction with the text in the accompanying chapter, the list can also serve as a handy double-check that all required work is done, as a journal to keep a record of parts cost, or as a checklist of miscellaneous items and steps that will make the job easier and more thorough. Also included is a list of major engine accessory components that should be inspected and replaced, if necessary, at this time.

BLOCK

Block

Clean, inspect

Bore, hone

Cam bearings

Core (freeze) plugs

Gallery plugs

CRANKSHAFT

Crankshaft

Straighten

Turn, polish

Damper pulley

Main bearings

Main bearing caps

Oil slinger

RODS

Rods

Straighten, align

Rod bearings

Rod caps

PISTONS

Pistons

Pins

Pin locks

Rings

OIL SYSTEM

Pan

Oil pump

Oil pump gearset

Bypass spring

Oil pump shaft

Oil fill tube

Dipstick

CAMSHAFT

Camshaft

Lifters

Pushrods

Rocker arms, shafts

Timing chain

Timing cover

Timing gearset

HEADS

Heads

Combustion chambers

Valve seats

Valves/int., exh.

Valve seals

Valve springs

Spring retainers

Spring keepers

IGNITION

Distributor

Points, condenser

Secondary wiring

Coil

Spark plugs

CARBURETION

Intake manifold

Carburetor

Air cleaner

Fuel pump

Fuel pump pushrod

Fuel filter

ACCESSORIES

Alternator, brackets

Water pump

Fan belts

Fan

Pulleys

Motor mounts

Starter motor, solenoid

Oil filter

Flywheel

MISCELLANEOUS

Gasket sets

Gasket sealant

Plastigage

STP

Loctite

Oil

Cam lubricant

Engine paint front

130 1

150 95 2

140 45 3

145 4

Engine Oiling

Diagnosing an engine oiling problem, such as excessive wear from lack of oil, or excessive oil consumption from too much oil, requires a lot more savvy than just knowing where the dipstick and the oil filler tube are. The engine oiling circuit diagrams that are in the shop manuals and also in the Petersen *Complete Book of Engines* are not there just to satisfy an engineering curiosity. Those diagrams will point out how the oil gets where it is supposed to be and may give you a clue as to why you are getting either too much or not enough oil.

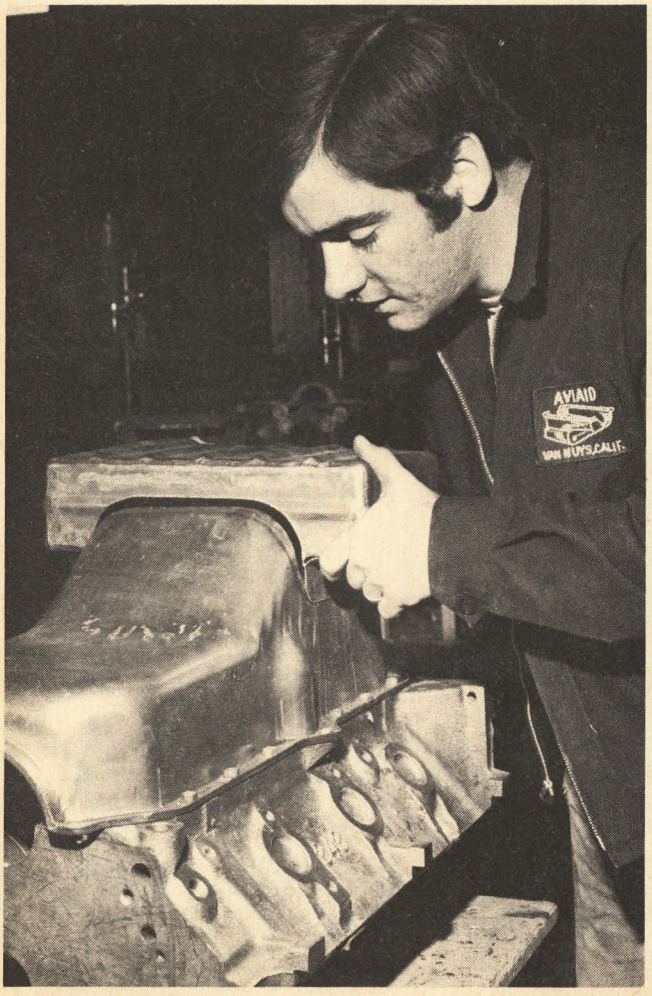
To fully understand the oiling system of an automobile engine, it is first necessary to understand something about oil itself. In an engine, oil is called on to reduce the friction between moving parts. This will reduce the destructive heat caused by excessive friction, conserve power, and reduce wear of contacting metal surfaces. Oil acts as a seal between the piston ring and cylinder to prevent combustion leaking down into the crankcase; it washes away abrasive metals worn from friction surfaces; and by flowing continually over heated surfaces keeps operating temperatures down. It must do all these things even if the weather should be desert hot or arctic cold.

Under ideal conditions, oil will form a thin film between two surfaces so that these surfaces never touch. Therefore, no metal wear would ever occur. Unfortunately, this ideal condition seldom exists. When ambient temperature is low, oil viscosity is such that the oil does not flow well during engine warm-up. When the temperature is hot, or high, the oil may thin too much and the lubricating film is easily broken. To be of maximum effectiveness, the oil must flow well at cold temperatures but maintain body at high temperatures. During this time, it must also keep an unbroken film between the metal parts.

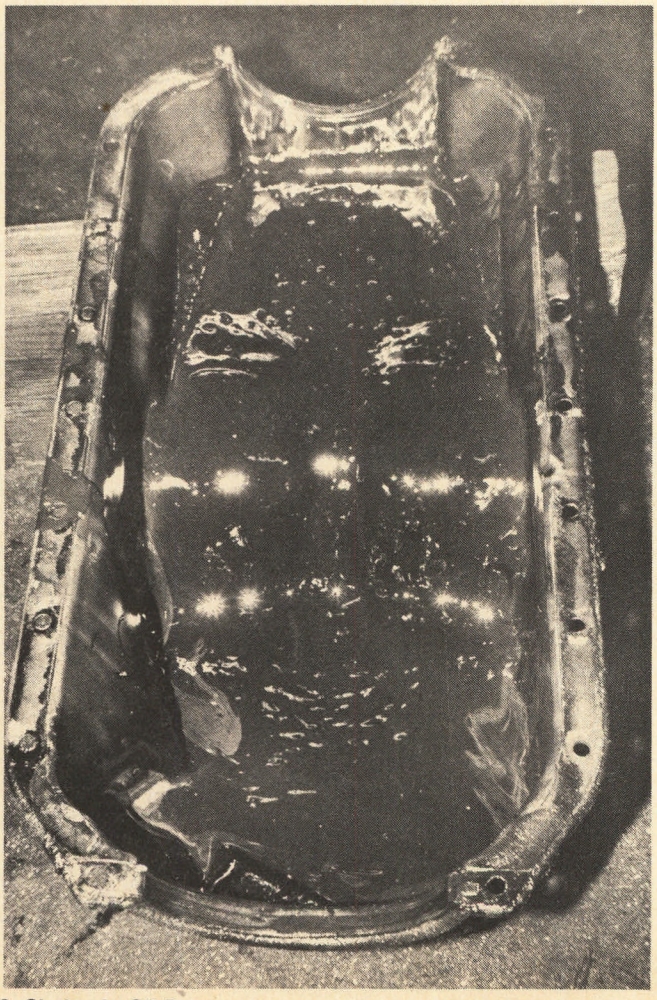
OIL PANS

Automotive engines use either a wet or dry sump oil reservoir. In the first, the oil is maintained at the proper quantity by a sump in the oil pan. In other words, all the oil is carried within the confines of the oil pan, but must be isolated from the revolving crankshaft by a baffled sump. In the dry sump system, which is something of a misnomer, the main oil supply is kept in a tank outside the engine. The engine oil pump draws the oil from the tank, then another pump scavenges it from the flat pan back to the tank. This type of system is common to aircraft, motorcycles, and racing engines. It is more positive and allows extra cooling because of greater oil capacity, but is also more expensive.

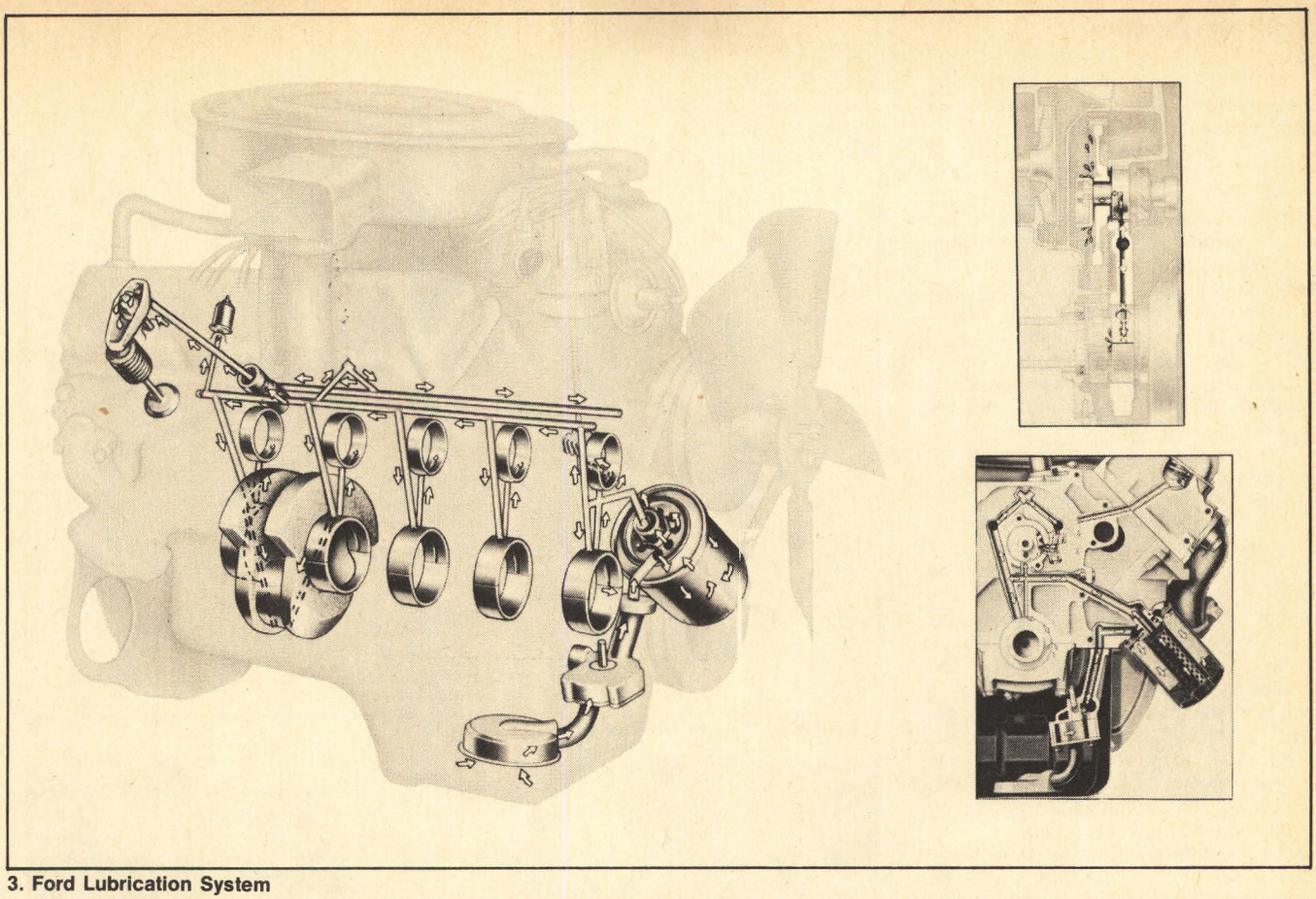
While the transmission and rear-end gears splash the oil around and thus lubricate themselves, the engine needs a more sophisticated approach. Every



1. Enlarging Oil Sump



2. Sludge in Oil Pan



3. Ford Lubrication System

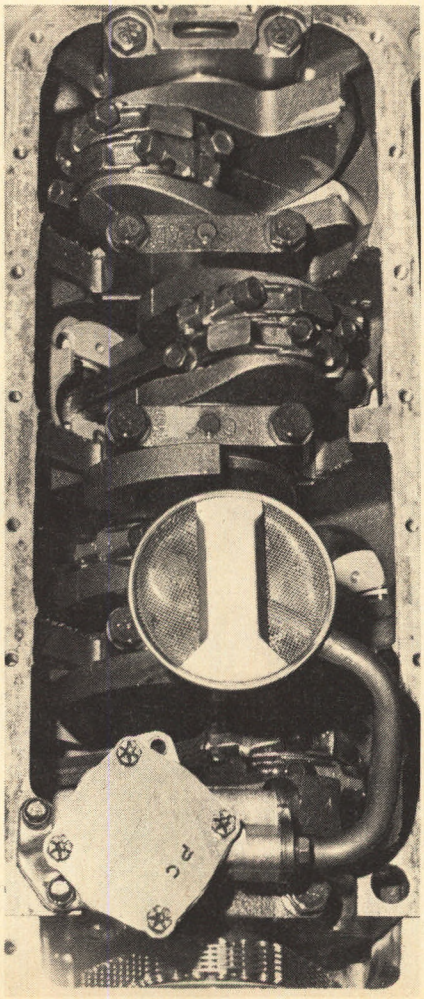
1. During high-speed operation, most of the oil normally in a stock pan is "in suspension," therefore little is ever found in the pan. By enlarging the oil sump of the pan, as seen here, more oil can be carried, thereby allowing any given quantity more time to cool before being circulated again, thus protecting the engine.

2. Ever try to lubricate an engine with molasses? In this instance molasses would probably be as effective as the oily sludge found in this pan. Such a condition indicates infrequent oil and filter changes, which will result in a marked decrease in engine life.

3. These illustrations show how oil is picked up in the pan, delivered through the filter, and carried through the galleries of the Ford 429 engine to lubricate the crank, cam, lifters, rockers and timing chain.

4. Oil pickups are covered with a filter screen to prevent the pump from sucking up any large foreign matter that may find its way into the pan sump. This pickup is stationary, whereas some can swing in an arc about the pan, following oil movement and thereby preventing oil starvation.

5. For best oil flow, considering the ambient temperatures, use an oil of recommended viscosity rating.



4. Pickup Filter Screen

OIL VISCOSITY CHART	
Lowest Temperature Expected	SAE Viscosity Number
Above +32°F.	SAE 30 SAE 20W-40 SAE 10W-30
+32°F. to +10°F.	SAE 20W SAE 10W-30
+10°F. to −10°F.	SAE 10W SAE 10W-30 SAE 5W-20
Below −10°F.	SAE 5W-20

5

moving part inside an engine must be oiled, from the crankshaft bearings to the valves. Splash is not the answer now, although it was common to the low performance engines of years past. It would not work today.

There are three basic types of oiling systems in engines: splash, modified splash and full pressure. In the first, the crankshaft splashed oil around inside the engine and gravity caused it to drain back to the pan. The modified splash design had little troughs across the oil pan. When the connecting rod revolved at the bottom of the stroke, oil was scooped up by dippers on the rod cap. An improvement of this was the addition of oil nozzle pipes that shot a stream of oil into the approaching dipper. Neither the splash nor modified splash are ideal. Most modern engines use full pressure lubrication, whereas an oil pump packs

the oil into a main delivery gallery and from there to the points of the engine that are in need of lubrication.

OIL PUMPS

These pumps are engine driven and draw oil through a screen on the pickup tube immersed in the pan sump. Depending upon the individual pump design, the oil is under a specific pressure and goes first to the oil filter (usually), then to the main oil gallery (gallery or header). From the main gallery (which is usually drilled in the cylinder block), the oil goes through secondary galleries to the crankshaft main bearings, camshaft bearings, timing drive mechanism, rocker arms, and lifters.

All this initial oiling route is usually within the confines of the cylinder block and in the case of overhead valves, the heads. Since these passages can, and do, get plugged, that is the reason for emphasis on cleaning during overhaul.

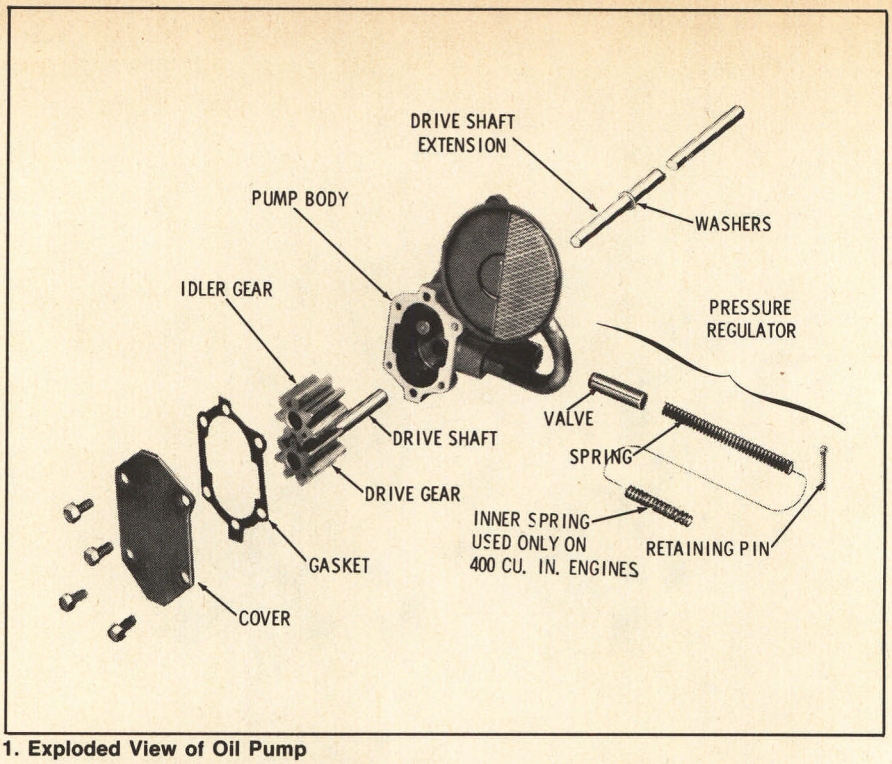
The oil pump is detachable from the cylinder block, and may be located in a number of different places. In some designs, such as Chevrolet and flathead Ford, the pump is actually immersed in oil near the sump; in others, the pump may be outside the block with an internal pickup leading to the sump.

Because different parts of the engine need a diffreent amount of oil, some kind of limitation must be placed in the delivery system. This is normally taken care of by the size of secondary delivery passages between the part and the main gallery, but often a further control is included in the bearing and/or bearing clearance. For instance, in some engines the various main bearings may require different amounts of oil, usually discovered during trial-and-error engineering by the factory. Restrictions in the passages take care of these requirements effectively.

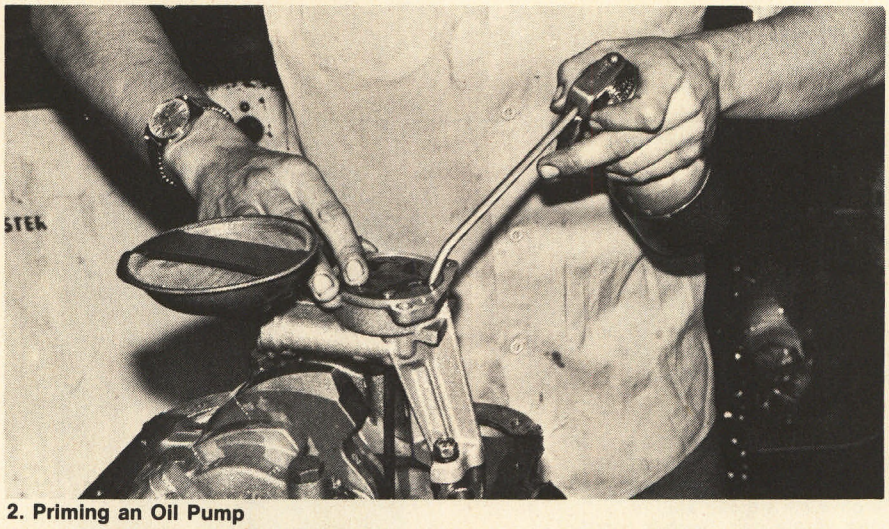
However, anytime an engine is modified for higher performance, the oil pump pressure is usually increased to around 80 lbs. to insure maximum pressure at critical bearing points. When this happens, it is possible to give too much pressure to a particular bearing, and a further restriction in the secondary passage may be necessary. This is often taken care of via drilled jets. Because this is a highly specialized practice, the amateur should never do it without expert direction.

At each crankshaft main bearing, the oil enters the bearing through a hole. Sometimes either the bearing surface or the crankshaft journal is grooved, either partially or the full circumference, to aid oil flow. Part of the oil thus delivered to the bearing will flow across the surface and out the sides to drop back into the oil pan. A greater majority will flow into a hole in the crankshaft journal that connects to the rod journals.

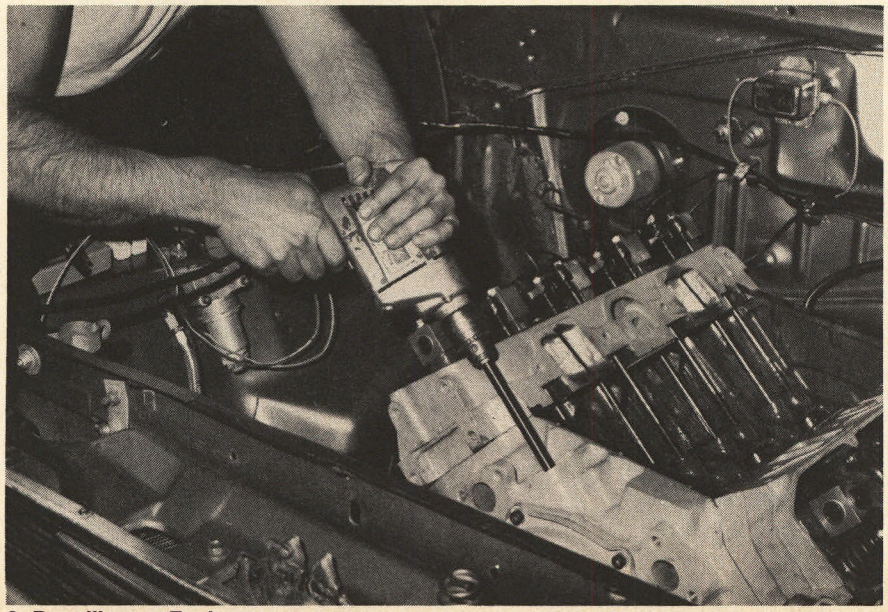
At the connecting rod bearings, the oil will flow across the bearing surface and out the sides to fall into the pan. In some engine designs, the connecting rods are drilled from the big end to the piston pin bore. If this is the case, the oil



1. Exploded View of Oil Pump



2. Priming an Oil Pump



3. Pre-oiling an Engine

1. This exploded view of a 1968 Oldsmobile oil pump illustrates the various components that go to make up such an assembly.

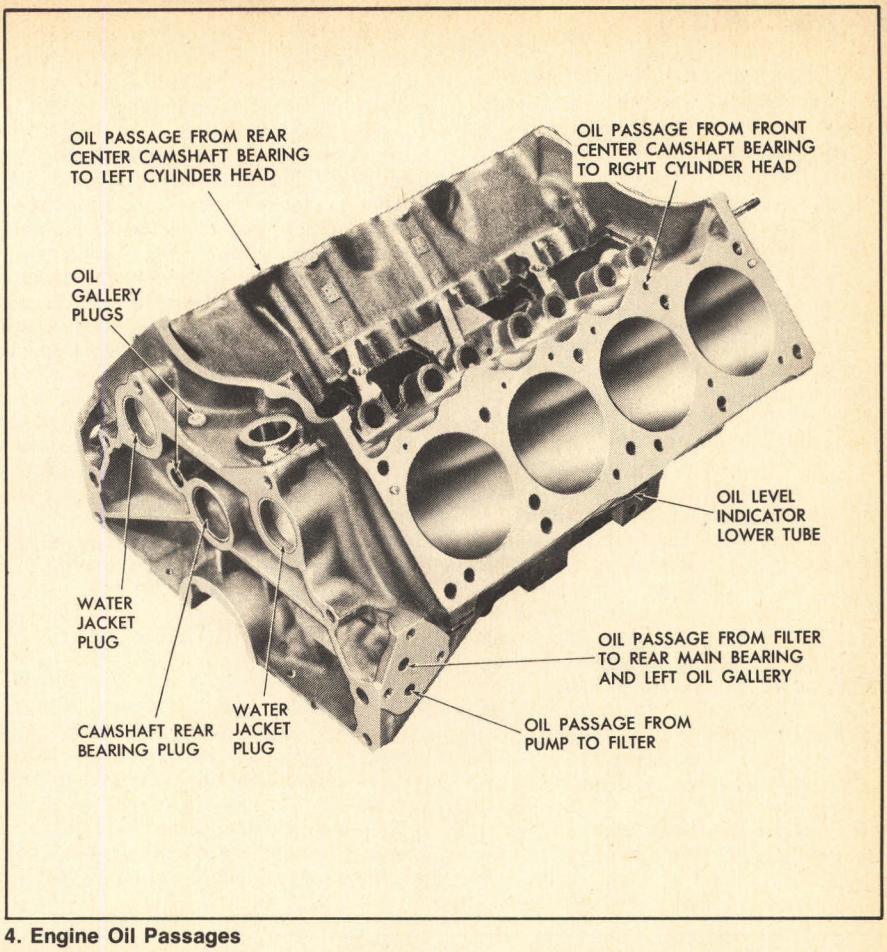
2. It's always wise to prime an oil pump when assembling an engine to avoid scouring the cam, lifters, bearings, etc. One method is to remove the oil pump cover plate and prime the cavity as the engine is being assembled.

3. It's a good idea with a rebuilt engine to pre-oil it by turning the oil pump shaft in the engine with a homemade tool that fits the shaft's slot. Turn with electric drill.

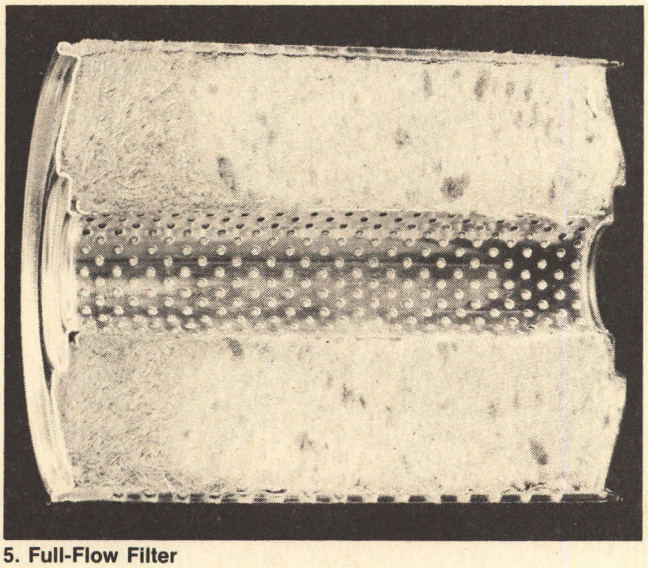
4. Block of typical V-8 shows oil passages. Note oil supply to rocker arms goes through gasket surface into head. Passage should be cleaned whenever head is removed.

5. Cutaway of filter element used in full-flow applications. The different material at left end of element is sisal, used to increase flow characteristics. This "sisal doughnut" was developed to allow depth-flow oil filters to pass the amount of oil needed in a full-flow oil system. The other element material is Vac-Cel, a mixture of cotton linters and rice hulls.

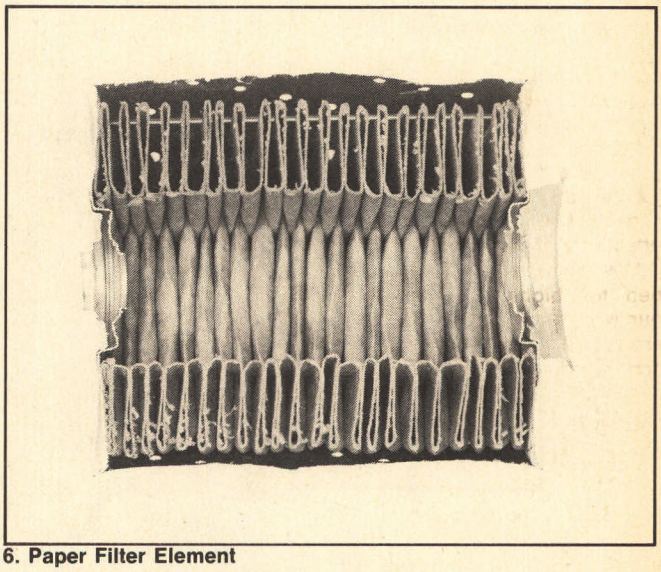
6. This is the type of element used on most new cars. Note that the oil is only required to pass through one thickness of the paper. This filter will last longer than the cotton type, but it does not filter as effectively.



4. Engine Oil Passages



5. Full-Flow Filter



6. Paper Filter Element

then continues up the rod and flows across the pin bushing before falling back to the pan.

Clearance of any and all bearings thus has a direct effect on total oil pressure within the full pressure system. If all the connecting rods have .0025-in. clearance, but one of the main bearings is worn and has excessive clearance, oil pressure will force more than normal oil through this bearing. Therefore, other bearings will tend to run at reduced oil flow.

While direct cylinder oiling has been tried by continuing the oil from the piston pin to a hole in the piston, the most common type of bore oiling is direct splash. When the crankshaft is rotating in the crankcase, it churns up considerable oil spray, which gets on everything in sight, including the cylinder walls. At the same time, as the rod journal goes through the top portion of rotation, oil being squeezed out the bearing surface is thrown on the walls.

At the front of the engine, some kind of oiling for the timing gears and/or chain is necessary. This may be either a direct or remote delivery, but the common system is from the front camshaft bearing. This oil is then thrown on the gears and chain and drains back into the block through a hole at the bottom of the chamber.

Oil to the valve system in overhead valve engines may be via internal or external passages, with the internal passage most common. An oil passage in the block mates with one in the head. The head passage passes the oil directly to a rocker shaft support and then out the shaft to the individual rocker arms. This supply is usually of low volume, but increases in direct consequence of engine rpm. As the oil squeezes out the sides of rocker and support bearings, it splashes onto the valve stem, and thus lubricates the valve guides. Getting the correct amount of oil to the rocker system is a definite problem on some older ohv engines, such as Ford design. In

these cases, an extra outside lube line may be installed (kits are available through most parts supply houses).

Many engines now use stud-mounted rocker arms which receive their oil flow through hollow pushrods. The same oil that operates the hydraulic lifter runs up through the pushrod and through a hole in the pushrod seat at the end of the rocker arm. The oil then runs down into the middle of the rocker arm and lubricates the pivot point at the rocker ball. After a few seconds of operation the rocker arms fill with oil, and then the oil spills over the rocker arm lip at the opposite end of the pushrod and runs down on the valve spring and the valve system. Too much oil on the valve system will flood the guide, and the the high vacuum in the combustion chamber will suck the oil into the engine. The amount of oil that is allowed to go through the guide into the engine is controlled by some kind of seal, which can be a simple O-ring underneath the valve keeper, a rubber umbrella that shields the end of the guide, or even a teflon seal that is a positive fit on the guide. At high rpm the oil that comes through the pushrod can squirt out and hit the rocker cover so that it runs down the inside of the cover without ever getting down in the rocker. The result can be burned rocker balls and very quick rocker arm failure. Many engines now have little tabs welded to the underside of the rocker covers to catch the oil at high rpm and let it drip back into the middle of the rocker for proper lubrication.

Because wear of all the working surfaces is normal, thus increasing bearing clearances and lowering final point oil pressures, most engines are equipped with pumps of large capacity. To control the oil pressure, then, a special bypass valve is installed, normally in the pump housing. When a predetermined oil pressure is reached, this spring-loaded valve is opened and the excess oil is bled back to the pan. As bearing wear increases, requiring slightly more oil pressure at the pump to compensate for a loss of pressure at the bearing, the relief valve is used less and less. It is possible to shim the pressure relief spring, carefully following engine manufacturer instructions, but under no condition should the spring be stretched in an attempt to increase the oil pressure.

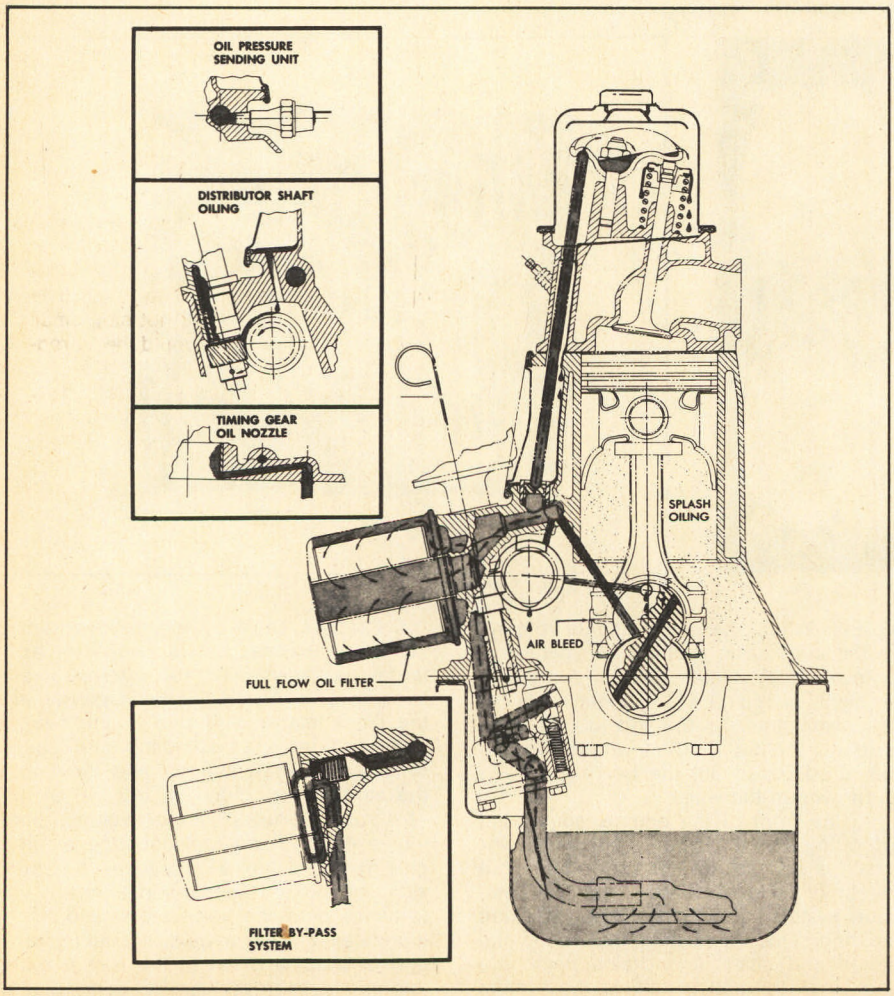
OIL FILTERS

Oil filters may be of full or partial flow design, and the included elements may be of cloth, paper, felt, or combinations thereof. In all cases, their prime job is to remove physical contaminants that get into the oil.

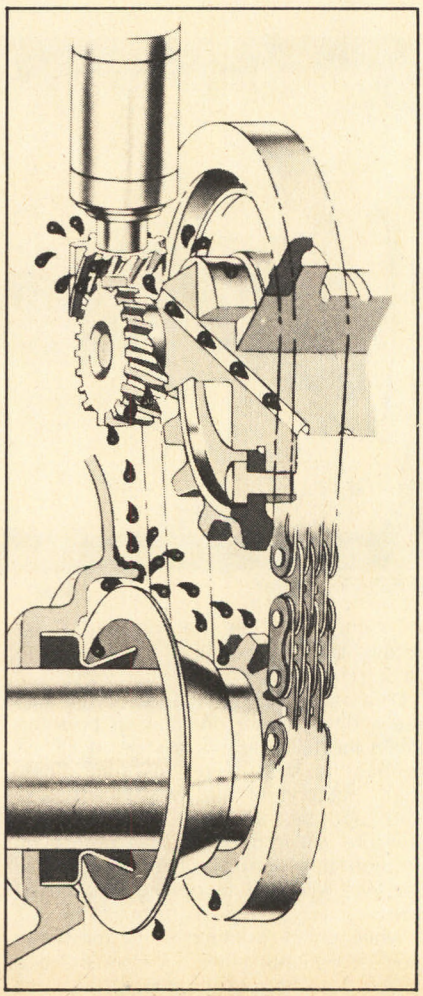
The full-flow filter passes all of the engine oil through the filter before it can reach the various bearing surfaces, while the partial-flow filter cleans only a portion of the circulating oil at any particular period. The advantages of the full-flow system are apparent, in that nothing harmful should reach the bearings. However, the full-flow filter does not filter constantly. Whenever the oil is cold or the filter is plugged with dirt, a bypass valve opens so that the engine can continue to get oil. Some engine designs have this bypass valve built into the engine block. In others it is in the filter can itself.

Some full-flow elements have a valve built into the element itself to prevent drainback into the pan. If the filter emptied every time the engine was shut off for a few hours, every start would be without lubrication. Because of this extra valve that works with the bypass valve in the engine, it is important that the correct filter element be used. Just because the element fits onto the mounting pad doesn't mean it will work correctly. The wrong element can ruin an otherwise good engine.

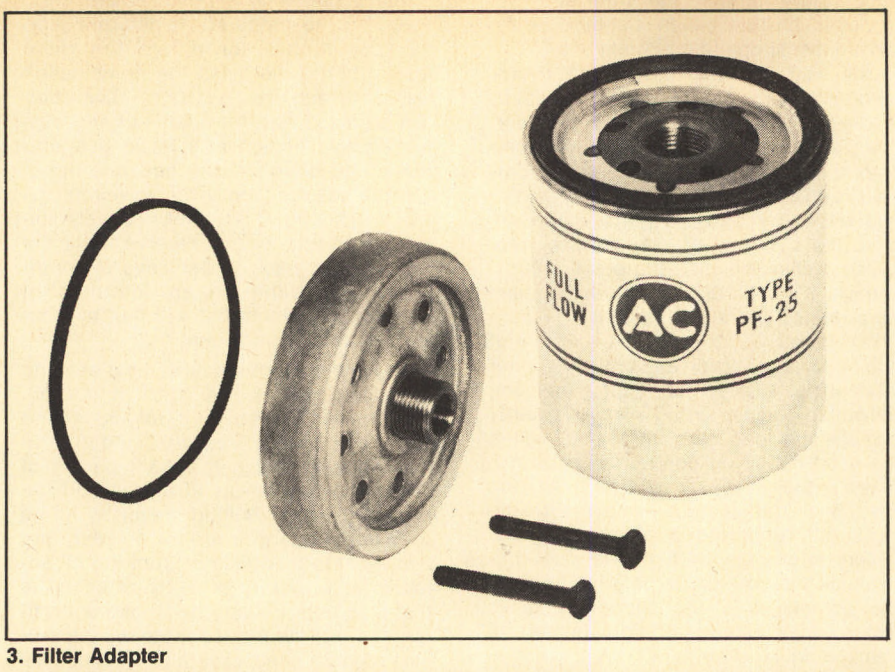
There are two types of engine oil filters available today: the depth type and the paper type. In the paper type a special paper is used that will stand up under the detergents, high temperature and pressure in an oil system. The paper-type elements are all designed to trap particles only. The better paper filters will trap particles that can be measured in millionths of an inch. The best paper filter we have heard of is the AC, which



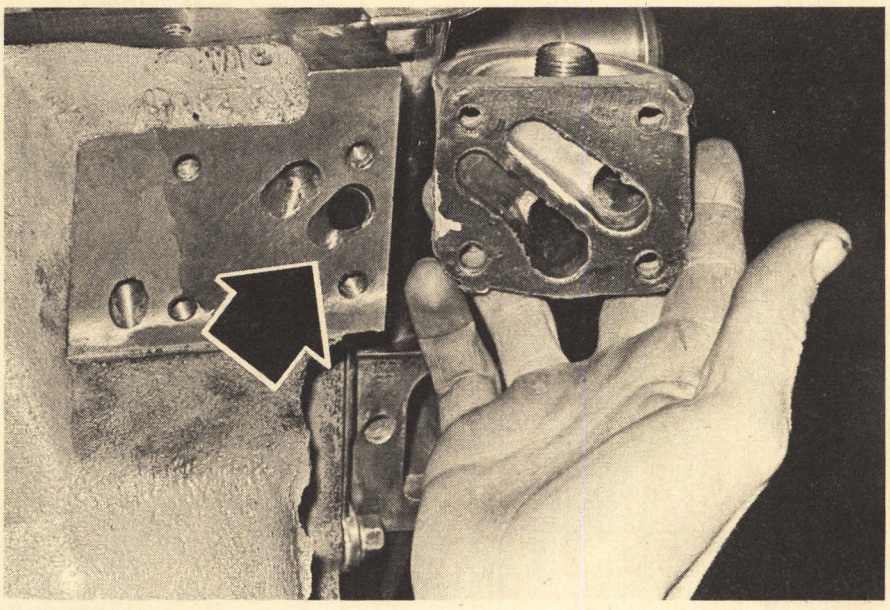
1. Six-Cylinder Lubrication System



2. Camshaft Drive Lubrication



3. Filter Adapter



4. Flared Oil Passage

1. In the oil's journey from the pan up to the rockers, it is pumped through a filter. If the filter is plugged with impurities, a bypass system will reroute the oil, as on this Chevy 6-cylinder.

2. A small oil gallery feeds oil directly to distributor gears, while splash takes care of the timing chain and its sprockets on this Buick design.

3. A number of companies have oil filter adapter kits for Chevy V-8 engines, '56 through '67, allowing use of modern disposable filters rather than the cartridges. This one is by AC, of General Motors.

4. It is wise to flare the oil passage on cylinder blocks, like this Ford, where the filter hooks up. Likewise, the same operation can be accomplished on Chevrolets where the pump rides on the rear main cap. All of these "tricks" are designed to improve oiling.

will trap particles as small as 30 microns, a micron being one thousandth of a millimeter.

Engineers who believe in the paper filter design say that it isn't necessary to refine the oil as you filter it. If you remove the solid particles—the grit and the dirt that do the damage to the rubbing surfaces in the engine—then it doesn't make any difference whether the engine oil is as clean as when it was first put in. A good paper filter will stop all of the solid matter but will pass any of the detergent or anything that is actually dissolved in the detergent.

Those who back the depth-type of filter, and this includes Ford Motor Co. because all of their engines are factory equipped with depth-type filters, feel that simple filtration of the solid particles in the oil is not enough. The depth-type filter not only removes solid particles but it attempts to remove water and other liquid contaminants that are actually dissolved in the oil. In a depth-type filter the oil has to pass through several inches of filtering medium. Oil will stay clear a lot longer with a depth-type filter, but one of the reasons it stays clear is that a certain amount of the detergent in the oil is being removed.

For many years, depth-type filters were not used on full-flow systems, because the extreme thickness of the depth-type filter would not pass cold oil. The result was a filter that only did half a job, because the bypass valve was open during a good part of engine operation.

The Baldwin Manufacturing Co. pioneered the use of a sisal doughnut in one end of the full-flow filter. The doughnut passed oil freely, but with very little filtering effect. The result was a filter with bypass action (filtering only part of the oil) on a full-flow system. A controversy still exists between the various filter companies over which is best for a full-flow oiling system—paper or depth type. Baldwin Manufacturing Co. stays out of the controversy by manufacturing and selling both types, for almost every car. Therefore you can pick whichever you think is the better.

What about toilet paper filters, the accessory gadgets that you buy and change yourself because very few service stations will have anything to do with them? Toilet paper filters are the depth-type but the trouble with them is they are too efficient. They not only remove the contaminants but they have a tendency to remove most of the detergent also. That's why a toilet paper filter will keep the oil as clear as if it had just been put in. Keeping the oil that clear is defeating the purpose of the detergent that we put in it in the first place. Those detergents have to circulate to do their job.

Toilet paper filters, in our opinion, must be changed at the recommended intervals in order to avoid shredding of the paper from the high temperature and pressure of the oil. There is a screen in the toilet paper filter can, but it is about the same mesh as ordinary window screen, and we feel it will not stop small particles of paper that could be shredded if the toilet paper were left in for long perods of time. We have personally disassembled an engine that had the crankshaft passages plugged with shredded toilet paper, but in all fairness to the toilet paper filter makers we feel that the engine had been run with the same roll of toilet paper a heck of a lot longer than the recommended period.

We do not like the look of dirty oil on the dipstick any more than anybody else does, but we must face the fact that oil in today's engines is designed to get dirty. It gets dirty because it's cleaning the engine, and it should be changed whenever it has become so loaded with contaminants that it can't do an effective cleaning job any longer.

If you keep a new car only a few months, it is doubtful that changing the filter or the oil will give you any benefit, other than keeping your warranty in effect. But if you keep your car, new or used, for several years, then filter elements and oil are cheap. The best of each will keep your engine running longer, with less trouble, if they are changed often.

Engine Oiling

OIL WEAR

Oil does wear out. It oxidizes. That is, it reacts with oxygen in the crankcase. It is mixed and broken many times, coming apart and going back together, to form oil blobs. In the process of oxidation, air will attach itself to broken molecules and react with the oil fragments. Eventually the hydrocarbon molecule becomes simply what we call "sludge." These products of oxidation are formed gradually (or rapidly) depending upon the temperature. The rate of oil oxidation remains relatively constant up to 150°. Thereafter, for every 10° rise in oil temperature, the rate of oxidation doubles. This oxidation rule is slow death to oil. It's like a disease. The rate of oxidation at 170° is twice that at 160°. It is four times at 170° what it was at 150°. At 230° however, it more than doubles; it begins to triple. Oil at temperatures over 250° rapidly becomes useless. Heat then is the greatest enemy of oil. At over 240°, the temperature across the interface becomes much hotter than it should be for safe frictional operating conditions.

One way of classifying sludge hydrocarbons is with regards to their solubility in the oil. We call them carbines, carboids, or carbides. Carbides are the ones that are abrasive. Some of the partially oxidized oil particles form varnish and will attack different parts of the engine. It's the duty of the additive contained within the oil to protect against varnish. It's your duty to protect against abrasives by changing the filter.

We found out a long time ago that adding even a small amount of a poor lubricant to a good lubricant gains one inevitable result: You always greatly damage the load carrying system within the good oil. If you don't change oil frequently, the pools of oxidized oil lying there in the engine will contaminate the fresh oil, rendering it almost useless. Failure to change the filter will also contaminate the new oil, largely blotting out the advantages of the change. It takes just a small amount of contaminant to damage an excellent oil.

RANGES OF SAE STANDARD SUS VISCOSITY

Wt.	Zero°F.	100°F.	210°F	
5W	4000 Max.			
10W	6000-12,000		35 Min.	Winter-grade
20W	12,000-48,000		40 Min.	Motor Oils
10	6000-48,000	150-270	40-45	
20	48,000-85,000	270-400	45-58	
30	85,000-125,000	400-700	58-70	
40	125,000-250,000	700-900	70-85	Motor Oils
50	250,000 Min.	900-1600	85-110	
60		1600-2100	110-130	
70		2100-4000	130 Min.	
5W-20	4000 Max.		45-58	
10W-30	12,000 Max.		58-70	Multi-grade
20-20W	48,000 Max.		45-58	Motor Oils
20-40	85,000 Max.		70-85	
75	15,000 Max.		40-48	
80	100,000 Min.	400-800	48-75	
90	200,000 Min.	800-1500	75-120	Gear Oils
140		1500-4000	120-200	
250		4000 Min.	200 Min.	
80-90	200,000 Max.		75-120	Multi-grade
90-140	300,000 Max.		120-200	Gear Oils

Courtesy of Valvoline Oil Company

This chart compares the various weights of oil according to their speeds of flow (SUS) at different oil temperatures. SUS (Saybolt Universal Seconds), as measured in a viscometer, is the number of seconds that it takes for one ounce of a particular oil to flow from one predetermined mark to another. So you can see that the ability of oil to flow to critical areas is greatly reduced when the oil is cold; therefore, a cold engine should not be revved up or raced. Thicker oil is best for heavy duty or racing because of higher viscosity at temperature, and multi-grade oils are thinner when cold, thicker when hot. As you'll note, the SUS viscosity of 90-wt. gear oil (200,000 minimum) is very similar to 40-wt. motor oil but due to a difference in additives, they can't be interchanged and to prevent this, they are assigned different weight numbers.

The additives in a good oil are engineered to be triggered at different temperature ranges for different surface loads. By this we mean the combination within the additive "package." The additive package has the load-carrying system to fight friction at specific temperatures. The designer may add one ingredient to ease friction under low-temperature conditions while other relatively stable ingredients wait in reserve, until the temperature rises under severe conditions. This achieves an interplay of chemical reactions that will suit a wide-ranging set of conditions.

To implement this action, heat-seeking metallic additives are used in the oil. Phosphates, polyamides, sulfonates and other compounds are attracted to the hot spots like magnets attract pieces of steel. As the additives in the oil and the steel react, the resulting chemistry forms a softer substance or flux powder that can eventually be filtered from the oil solution. A necessary property of an oil is that it be able to carry away debris particles, as well as reduce large wear particles (debris) chemically into smaller particles that are more easily dissolved. Typically, a good detergent oil is better able to carry these particles to the oil filter. At times, these particles settle in various parts of the engine, or transmission or rear end because they are no longer soluble. As they precipitate, they form sludge, dirt, plastics, and large abrasive particles in the bottom of the oil pan.

Frequent oil changes are necessary to eliminate this debris and the broken oil molecule fragments which also become sludge particles. To insure against this undesirable matter re-entering the oiling system, it is a good practice to change oil every 1000 miles. Car manufacturers would rather say that you can change oil every 4-, 5-, or 6 thousand miles. Yet we have seen cruddy black oxidized oil come out of a car after only 600 miles. It's acidic, contaminated, and totally used up. A good motto might be, oil is cheap. That's right! Oil is cheap, engine parts are not.

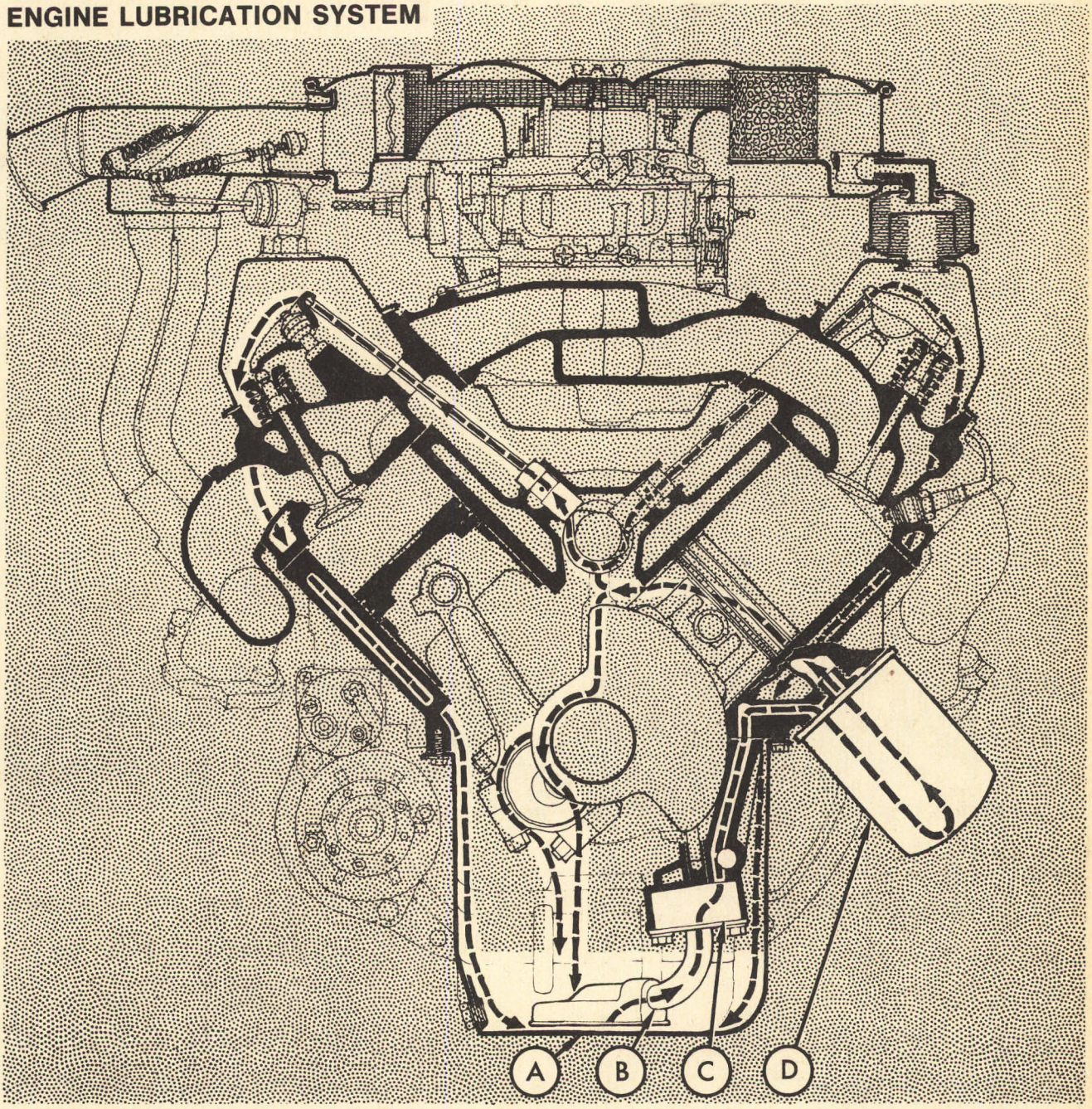
Oil changes could be stretched to 4000 miles if a car is equipped to run on propane. There's no dilution to speak of, so the oil stays fresher. Apparently, gasoline, being much more difficult to vaporize, washes the oil away from the top rings and wears out engines five times quicker than propane. Consequently, frequent oil changes are most important with gasoline engines.

We've seen that the addition of old oil residues into fresh oil causes damage to the new oil. It has also been proven that mixing two good oils together can result in a slightly worse lubricant than either of the two in the beginning. The additives that go into a package are selected to perform specific jobs. and different additives may fight one another, if an oil is improperly blended. Oil engineers spend many months of research to properly mix the base oils and additives. So stick with one good brand and one viscosity, avoid any mixing and change it frequently. With this type of maintenance, an engine can be expected to last well beyond the 100,000-mile mark with little sign of wear.

ENGINE OIL PRESSURE PROBLEMS

Among the most critical elements inside an automobile engine are the oil supply and the components which deliver the oil to areas in the engine where it will be used. No engine could run more than a few minutes without oil to lubricate moving parts and reduce friction. Without a lubricant, moving parts that come in contact with each other would start to fail.

ENGINE LUBRICATION SYSTEM



The engine lubrication system consists of a sump (A), the oil pan at the bottom of the engine that holds a supply of oil; a pickup tube (B) inside the sump; an oil pump (C) that forces oil through the engine; and a filter (D) which cleans the oil and removes metal particles, carbon and other foreign materials from the oil.

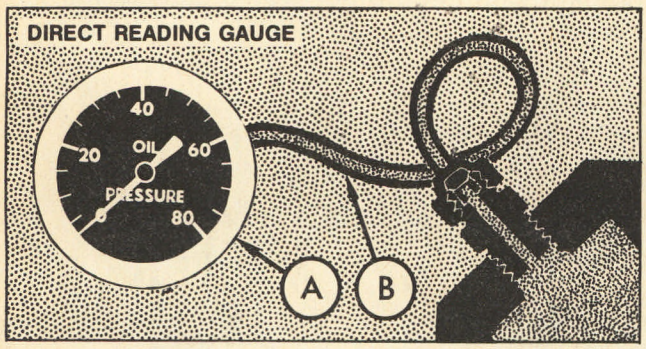
Oil is picked up from the sump by the pickup tube. It passes through the pump, through the filter and into the engine oil galleys (galleys are the holes or passageways inside the engine block and heads which route the oil to the various parts of the engine). The oil is in constant circulation while the engine is running.

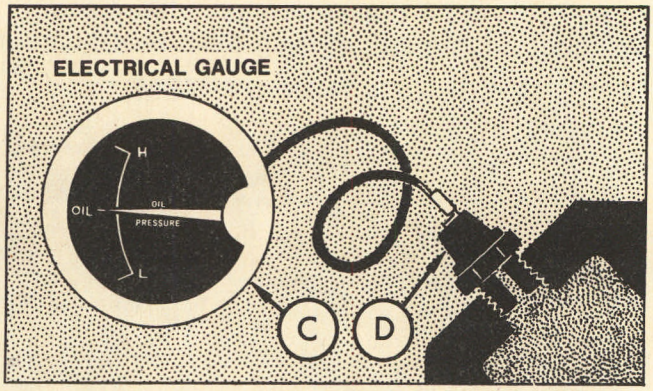
One good indicator of engine condition is the amount of oil pressure being delivered by the oil pump. Without oil, moving metal surfaces will rapidly wear or heat up due to friction. If the heating problem becomes severe enough, the moving parts of the engine can actually

ENGINE OIL PRESSURE PROBLEMS

melt or weld themselves together. Below is a list of things that can cause a low oil pressure reading.

OIL PRESSURE GAUGE



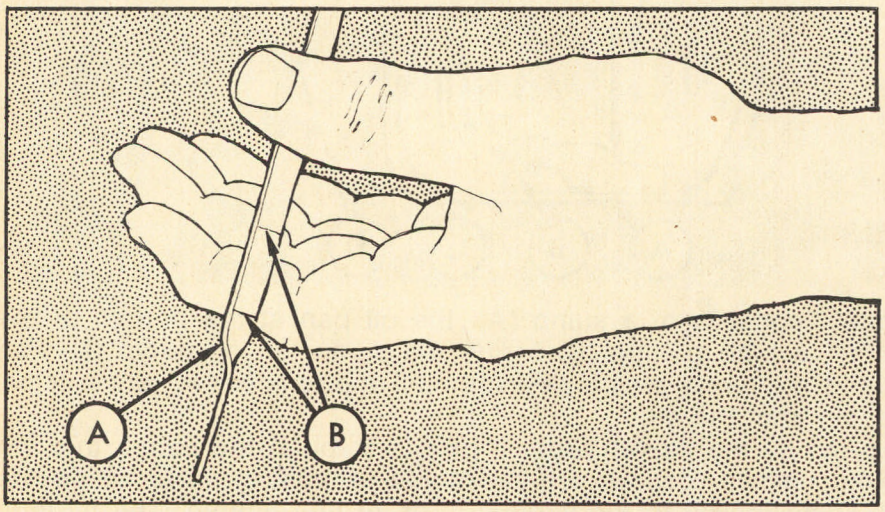


Remember to *check the obvious first!* The gauge or warning light mounted in the dashboard of your car may be the problem. These gauges and lights are designed to give a warning of low or no oil pressure, but they can fail even if there is no real problem in the oil system.

There are two basic types of oil pressure warning systems. One uses direct oil pressure through a length of tubing (B) which carries oil directly to a dashboard-mounted gauge (A). The other, much more common system is electrical. It uses a sensor (D) in the oil system which converts oil pressure into an electrical signal and sends it to the gauge (C) by wiring. Both do the same job, and checking them is about the same. Look for broken or pinched tubing or wiring to the gauge, leaking oil around the sensing unit or any other unusual conditions. Also, direct-reading gauges which use tubing should be checked to be sure that the tubing is not clogged with debris. Electrical gauges can be checked with a test meter (see detailed checks of automobile electrical accessories). Those electrical systems which use a warning light can be checked in the same manner.

CAUTION: IF THE OIL PRESSURE GAUGE OR WARNING LIGHT INDICATE A LACK OF PRESSURE, STOP THE ENGINE IMMEDIATELY AND DETERMINE WHAT THE PROBLEM IS. IF THE PROBLEM IS NOT IN THE GAUGE OR SENDING UNIT, RUNNING THE ENGINE WITH NO OIL PRESSURE WILL CAUSE SEVERE ENGINE DAMAGE.

LACK OF OIL



Low engine oil pressure can occur if the amount of oil available to the engine is reduced. If the oil level becomes low enough, engine damage can result. Checking oil is done by removing the dipstick (A), a metal shaft which reaches into the oil pan to show oil level. The dipstick is marked with lines (B) to show the proper oil level. If a check of the dipstick shows a low oil level, you may need to refer to the sections on oil leaks and excessive oil consumption.

CAUTION: DO NOT RUN THE ENGINE WITH LITTLE OR NO OIL. SEVERE ENGINE DAMAGE WILL RESULT.

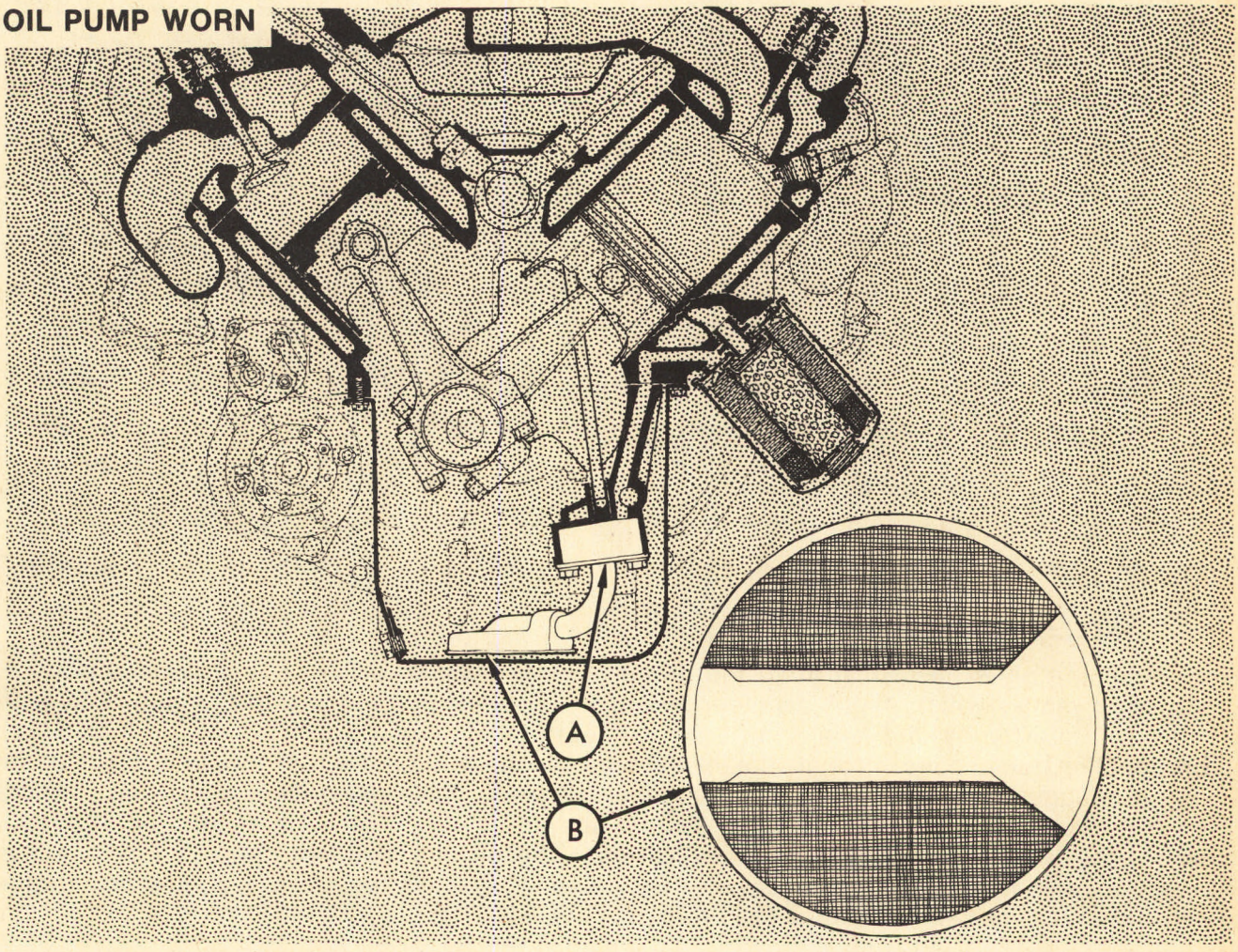
OIL TOO THIN

Low engine oil pressure can sometimes be the fault of oil that has been thinned out by water or gasoline. If examination of the dipstick shows tiny bubbles of water or the oil smells strongly of gasoline, something is wrong. The engine should be torn down to check for blown gaskets or other possible problems, such as a crack in the head or block.

Low oil pressure can also occur if the oil is the wrong weight.

NOTE: OIL WEIGHT DESCRIBES ITS VISCOSITY OR THICKNESS. FOR EXAMPLE, A LIGHTWEIGHT OIL IS A 10 WEIGHT, WHILE THE STANDARD WEIGHT OF MOST AUTOMOTIVE OILS IS 30 WEIGHT. IF THERE IS ANY DOUBT THAT THE WEIGHT OF THE OIL IN THE ENGINE IS CORRECT, DRAIN IT AND FILL THE CRANKCASE OR SUMP WITH THE MANUFACTURER'S SUGGESTED WEIGHT OIL.

OIL PUMP WORN



The oil pump (A) used to circulate the oil inside the engine is a gear-driven type. Several kinds of wear on moving parts or the failure of a gasket in the pump can reduce the pump's ability to pump oil. These are not problems easily found and repaired by the home mechanic, as they require removal of the oil pan to get at the pump.

NOTE: SOME PUMPS ARE MOUNTED OUTSIDE THE OIL PAN WITH THE PICKUP INSIDE.

OIL INTAKE SCREEN CLOGGED

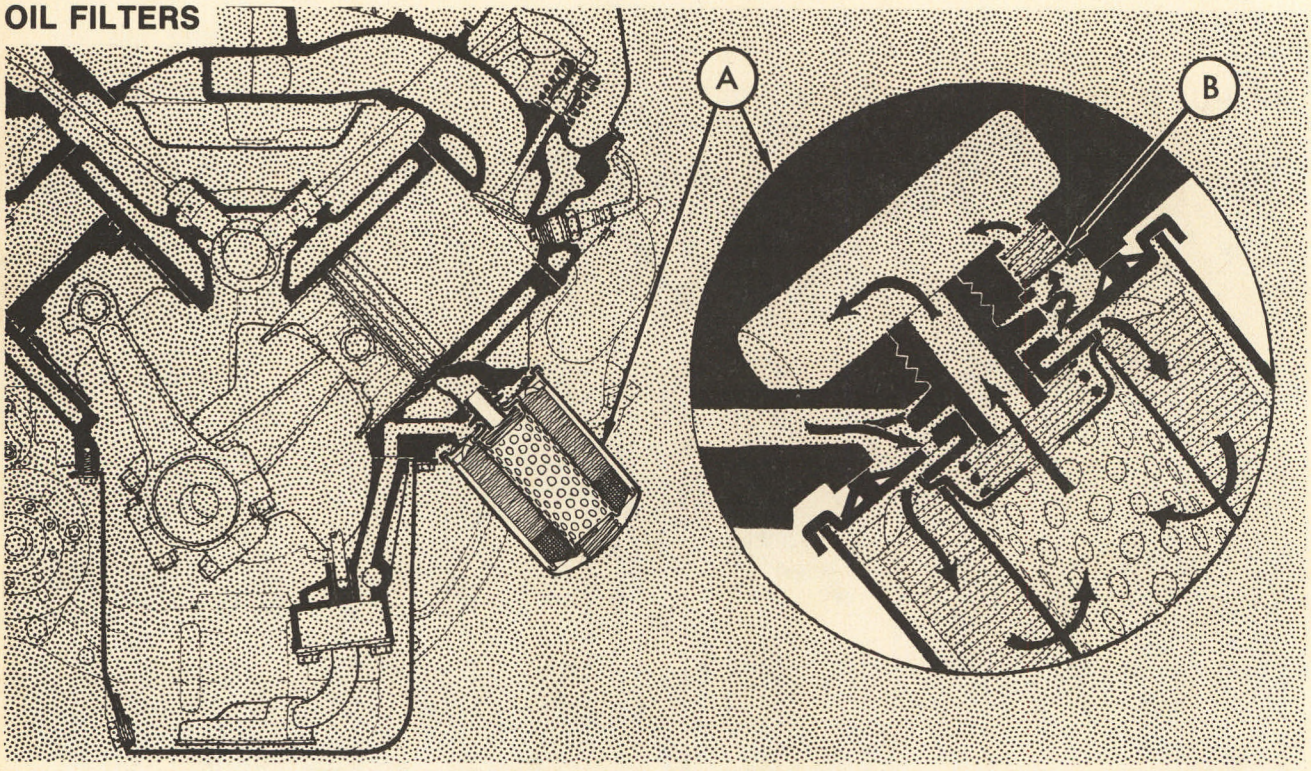
The oil pickup (B), which rests in the bottom of the oil pan, sucks up oil, which is then passed through the pump and on to the rest of the lubrication system. The pickup is usually fitted with a filter in the form of a mesh screen. This mesh screen can become clogged with debris if the oil is not changed regularly. The oil pressure in the engine will drop if the pump cannot pick up enough oil.

ENGINE OIL PRESSURE PROBLEMS

OIL PRESSURE RELIEF VALVE

Incorporated inside the oil pump is a spring-loaded relief valve which maintains engine oil pressure within certain limits. As the engine rpm increase, so does the speed of the oil pump. It often pumps oil faster and at a higher pressure than is necessary to lubricate the engine. At a certain limit, the excess pressure opens the relief valve and allows some of the oil to go directly back to the pan without going to the rest of the engine. This lowers both the oil volume and pressure. If the relief valve sticks or becomes weak, however, it will not allow the oil pressure to come up to normal limits.

OIL FILTERS



After the oil is passed through the pump, it goes through a filter (A) to remove particles and other matter which might damage bearings and other parts inside the engine. There are two basic filter types: *full flow* and *partial flow*. In the full-flow design, all the oil that passes through the pump goes through the filter to be cleaned, except when the oil is cold or the filter is plugged with dirt. When this happens, a bypass valve (B) opens, bypassing the filter to provide oil to the engine. The other system, the partial-flow filter, only receives and filters a part of the engine oil at any one time. Normally the oil filter will not cause a low or no oil pressure reading unless (in the case of the full-flow system) the filter becomes so clogged with dirt and debris that it also plugs the bypass valve.

AIR LEAK IN PICKUP TUBE

If the oil level is very low in the pan, the upper part of the screen at the pickup tube end may be exposed to air. The oil pump will then be pumping air instead of oil (this is called pump cavitation). Also, it is not uncommon for the pickup tube to come loose from the pump housing or to develop a crack which permits air to enter the pump.

WORN BEARINGS

As main, rod and camshaft bearings wear during their normal service life, the clearance between their surfaces becomes larger. Since a larger volume of oil is then required for lubrication, lower pressure results.

NOTE: IF WORN BEARINGS ARE BAD ENOUGH TO CAUSE A SERIOUS DROP IN OIL PRESSURE, CHANCES ARE GOOD THAT YOU WILL HEAR SOME OF THE ENGINE NOISES ALREADY DESCRIBED IN THIS CHAPTER.

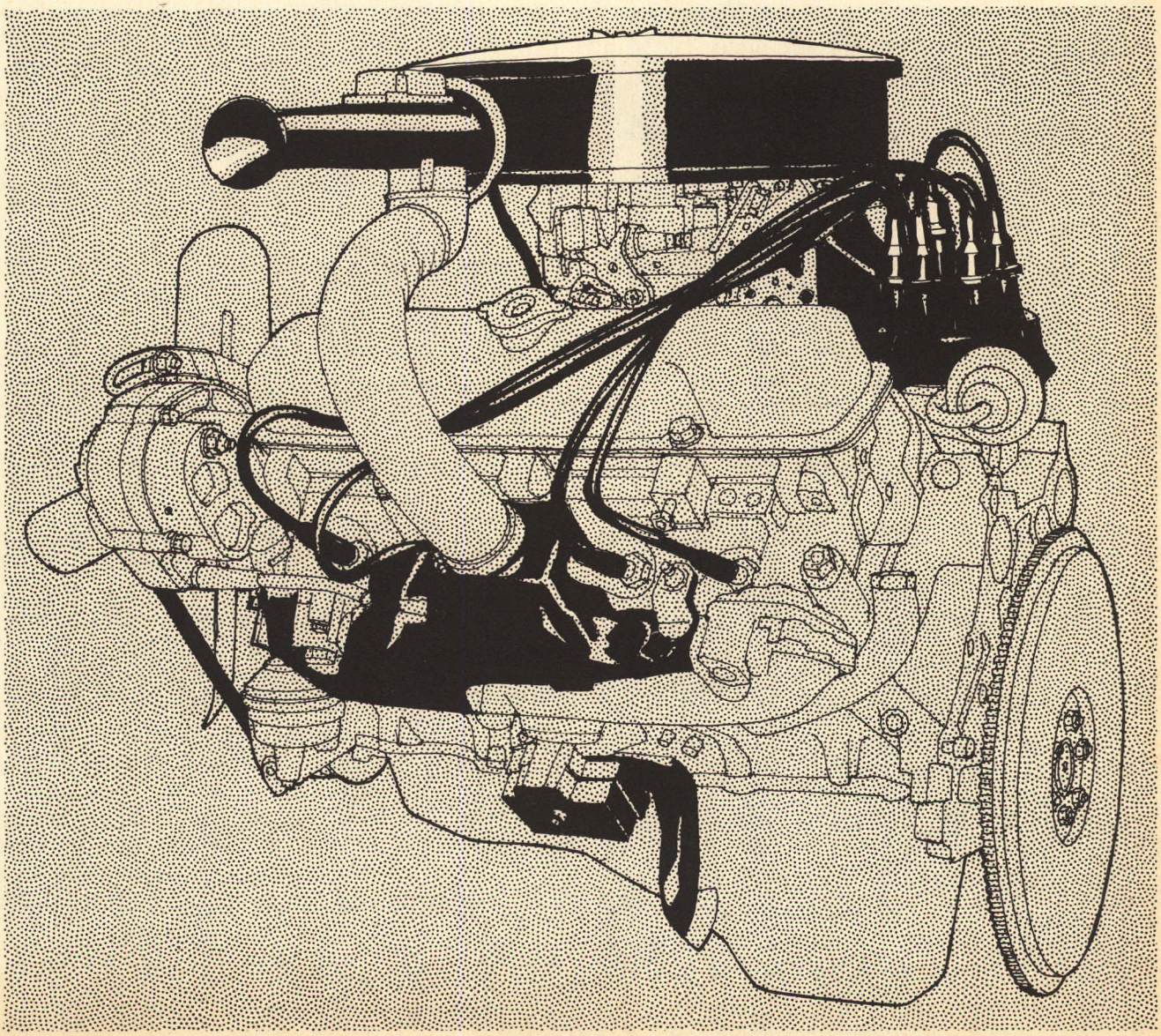
NO OIL PRESSURE

CAUTION: IF THE OIL PRESSURE GAUGE OR WARNING LIGHT INDICATE A LACK OF PRESSURE, STOP THE ENGINE IMMEDIATELY AND DETERMINE WHAT THE PROBLEM IS. IF THE PROBLEM IS NOT IN THE GAUGE OR SENDING UNIT, RUNNING THE ENGINE WITH NO OIL PRESSURE WILL CAUSE SEVERE ENGINE DAMAGE.

If the reading on the oil pressure gauge is zero or if the oil warning light comes on and stays on, the problem areas are exactly the same as those already outlined in the section on low oil pressure. CHECK THE OBVIOUS FIRST. If a check of the gauge or warning light system fails to turn up the problem, you must assume that something major is wrong with the engine lubrication system. (For more information, see the shop manual.)

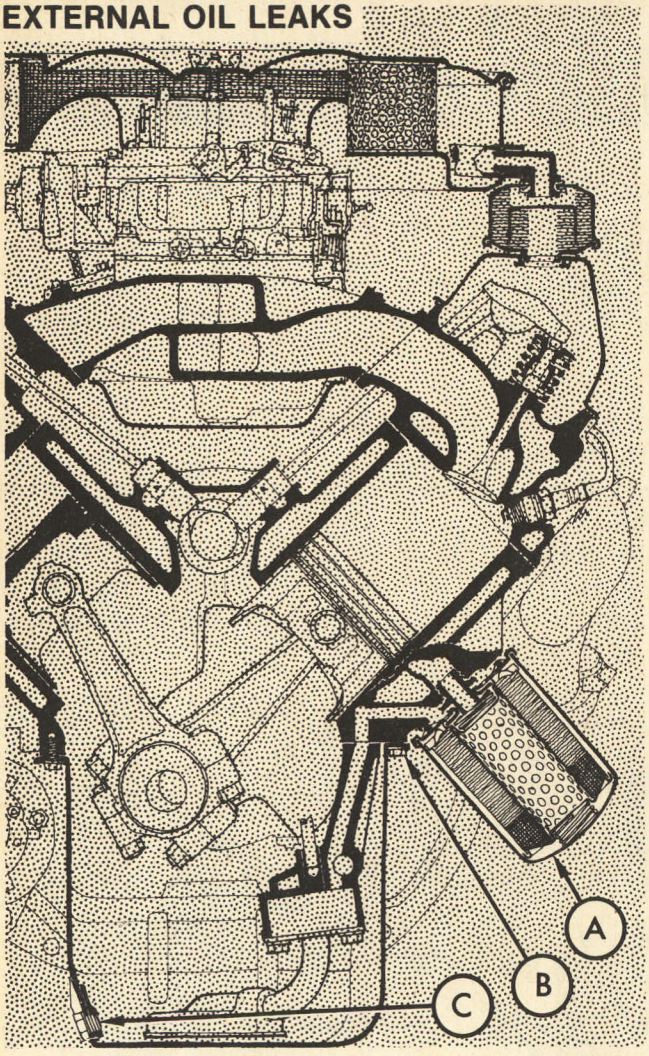
HIGH OIL PRESSURE

If oil pressure reads much higher than normal, several things could be wrong. (You will not get an indication of high oil pressure with the light system.) First, check the gauge to make sure that it is working (not physically broken and the wiring to the gauge not damaged). Then determine that the oil used is the correct type and weight for the engine. Too heavy an oil weight will cause a high-pressure reading. Other things that could cause this are: The oil pressure relief valve adjustment could be set too high, or the valve could be stuck shut by sludge. It is also quite possible that the main oil passages on the pressure side of the pump are clogged with sludge.



EXCESSIVE OIL CONSUMPTION

EXTERNAL OIL LEAKS



Excessive oil consumption can result from engine oil simply leaking out through openings in a gasket or at points where two parts of the engine are joined (valve cover to heads). Other spots where oil leakage can be expected are around oil seals and around moving parts that leave the inside of the engine, such as the crankshaft seals around the fore and aft ends of the crank, where the crankshaft exits from the engine.

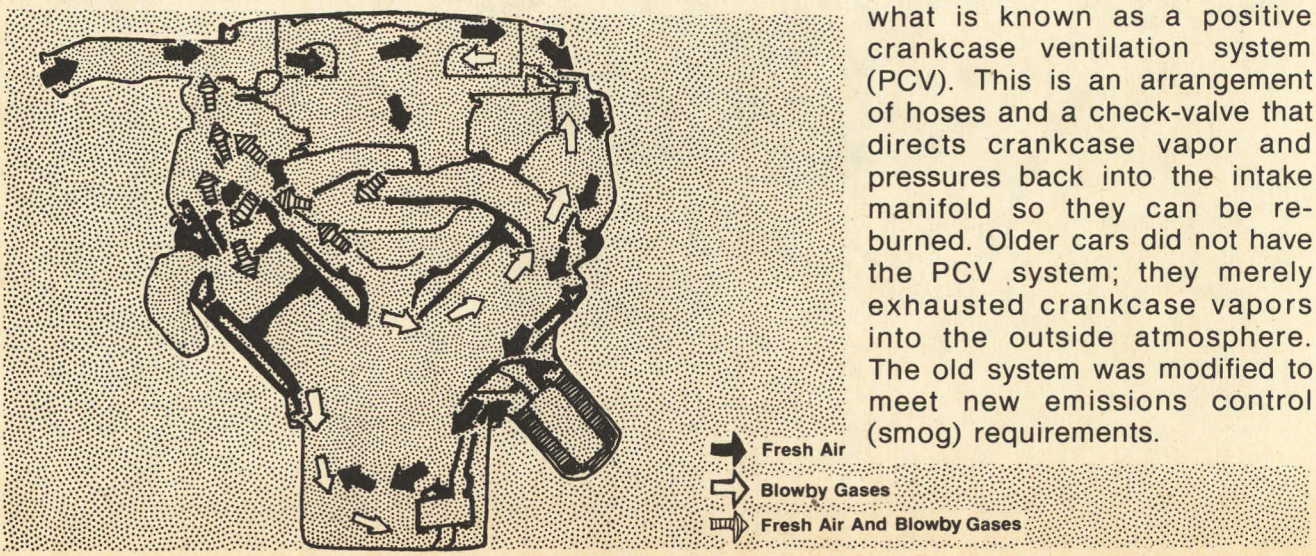
The most common points of oil leakage are around the oil filter (A) and around the edges of the pan (B) and the pan drain plug (C). A small loss of oil will occur at these points when the oil is changed, but large amounts of oil on the underside of the engine or on the inner fender areas indicate a major oil leak.

Fresh oil coming from the inside of the engine will be cleaner than oil that has been outside the engine long enough to attract dirt. If the oil leak is really severe and has coated a large area, it may be necessary to steam clean the engine compartment before checking the location of the leak. Once the leak has been found, it can often be cured simply by tightening the part that is leaking. For example, engine valve covers often develop small leaks, because the screws holding them down vibrate loose. In the case of gaskets that leak even when the part is tightly bolted, the gasket should be replaced. Refer to the shop manual for correct procedures.

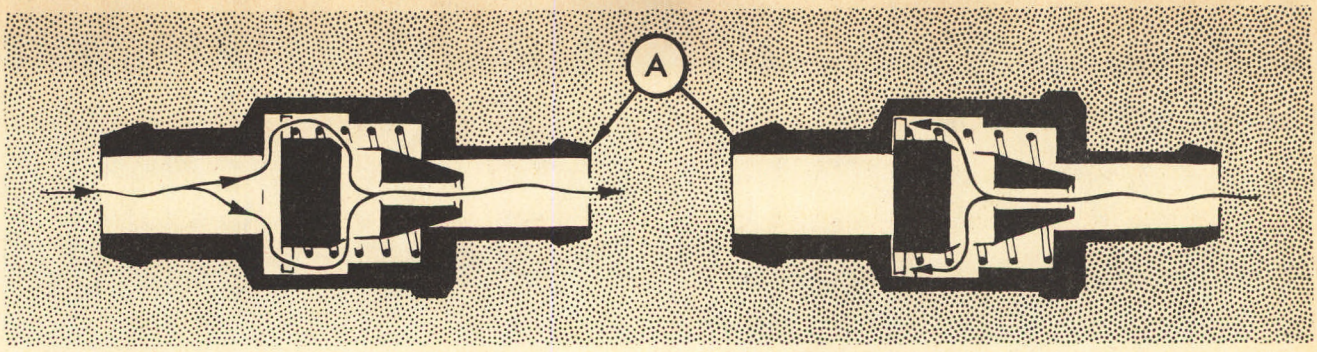
External oil leaks are often caused by blowby, a problem created when piston rings become so worn that they allow combustion chamber pressure to force its way past them and pressurize the oil pan area. This forces oil out around the pan gasket and other areas that don't leak under normal oil pan pressures.

Blowby usually happens when the crankcase ventilating system is plugged up and unable to relieve the pressure

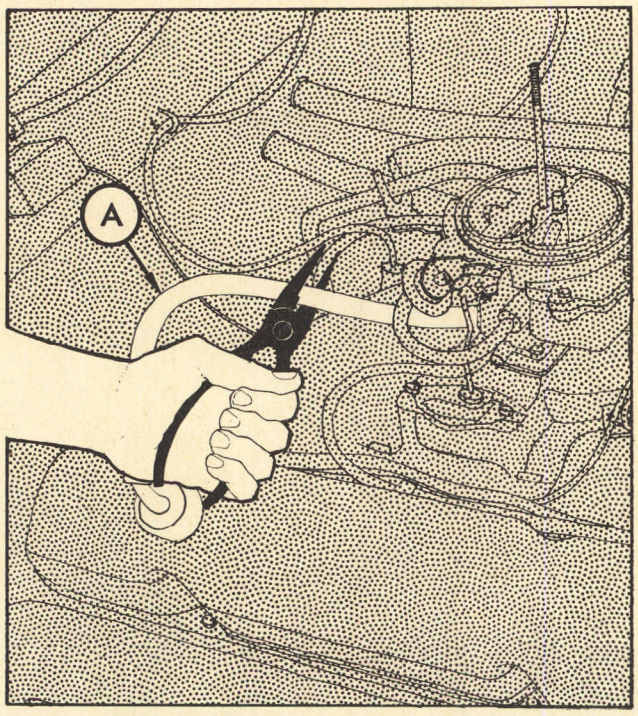
CRANKCASE VENTILATION SYSTEM

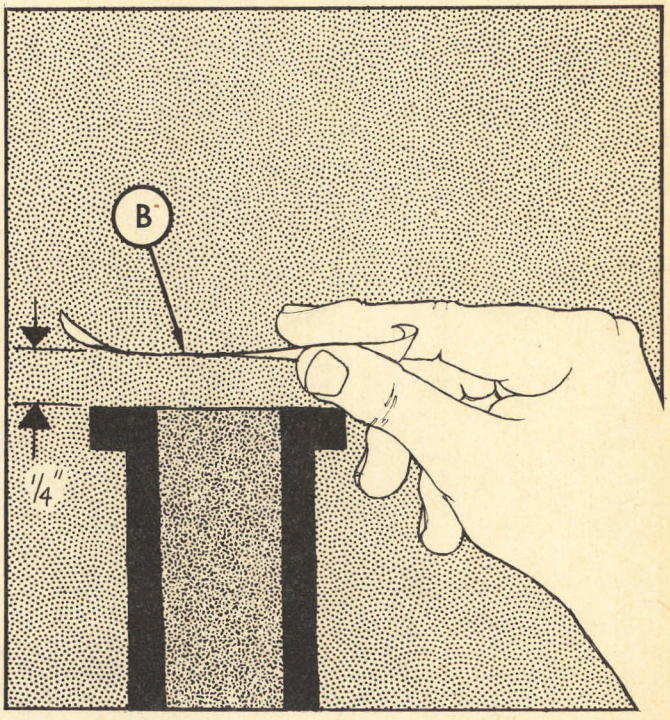


Modern automobiles have what is known as a positive crankcase ventilation system (PCV). This is an arrangement of hoses and a check-valve that directs crankcase vapor and pressures back into the intake manifold so they can be reburned. Older cars did not have the PCV system; they merely exhausted crankcase vapors into the outside atmosphere. The old system was modified to meet new emissions control (smog) requirements.



The check valve (A) used in most forms of PCV systems is a simple one-way valve used to prevent the reverse flow of air through the system. The valve can become plugged with dirt and sludge. If this happens, the system cannot relieve the pressure inside the crankcase and oil can be forced out, resulting in leaks.





To check the PCV valve, first locate the hose leading from the valve cover or the side of the crankcase to the base of the carburetor. At some point in this line you will find the PCV valve. Start the engine and let it run until it reaches normal operating temperature. Pinch the hose (A) shut with a pair of pliers.

CAUTION: BE SURE PLIERS HAVE SMOOTH JAWS OR YOU'LL DAMAGE THE HOSE.

If the PCV system is working, the engine's idle rpm will drop between 60 and 100 rpm (an audible drop). If the rpm do not drop, there is a good chance that the PCV valve is plugged.

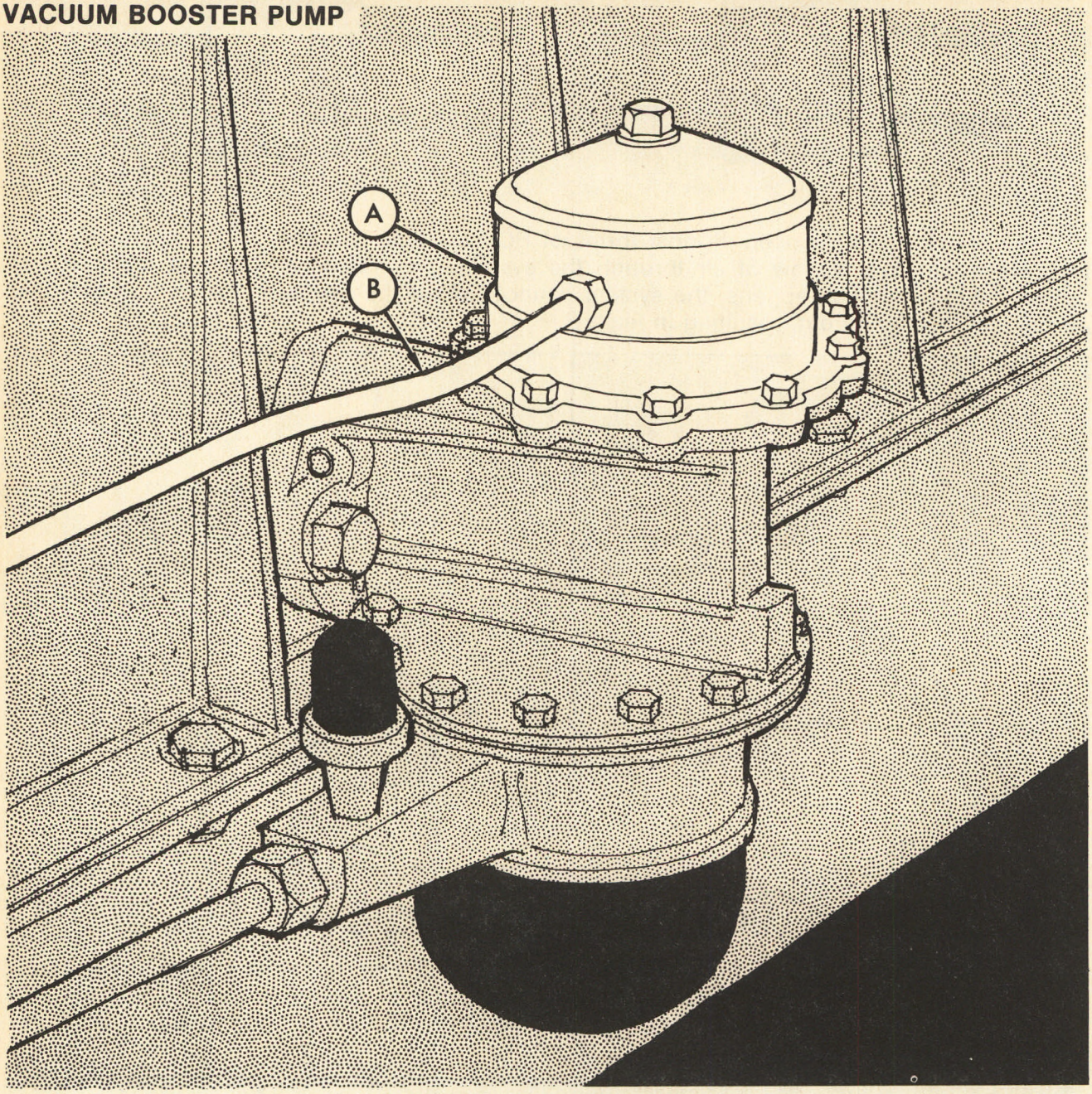
A second method of checking the operation of the PCV system is to remove the oil filler cap and hold a small card or light piece of paper (B) approximately ¼-inch from the opening. With the engine running, suction in the crankcase should pull the paper to the opening.

Some PCV valves can be taken apart and cleaned in solvent, while others are simply thrown away and a new one installed. It's a good idea to replace PCV valves at each tune-up.

NOTE: IF THE PCV VALVE WAS BADLY CLOGGED, THE HOSE MAY ALSO NEED TO BE INSPECTED AND CLEANED BEFORE IT IS REINSTALLED ON THE ENGINE.

EXCESSIVE OIL CONSUMPTION

VACUUM BOOSTER PUMP



On cars equipped with a vacuum booster pump (A) to operate vacuum windshield wipers, excessive oil consumption can occur if the diaphragm (flexible disc inside the vacuum pump) tears or becomes porous. When this happens, the vacuum sucks oil vapor from the crankcase and sends it to the intake manifold area.

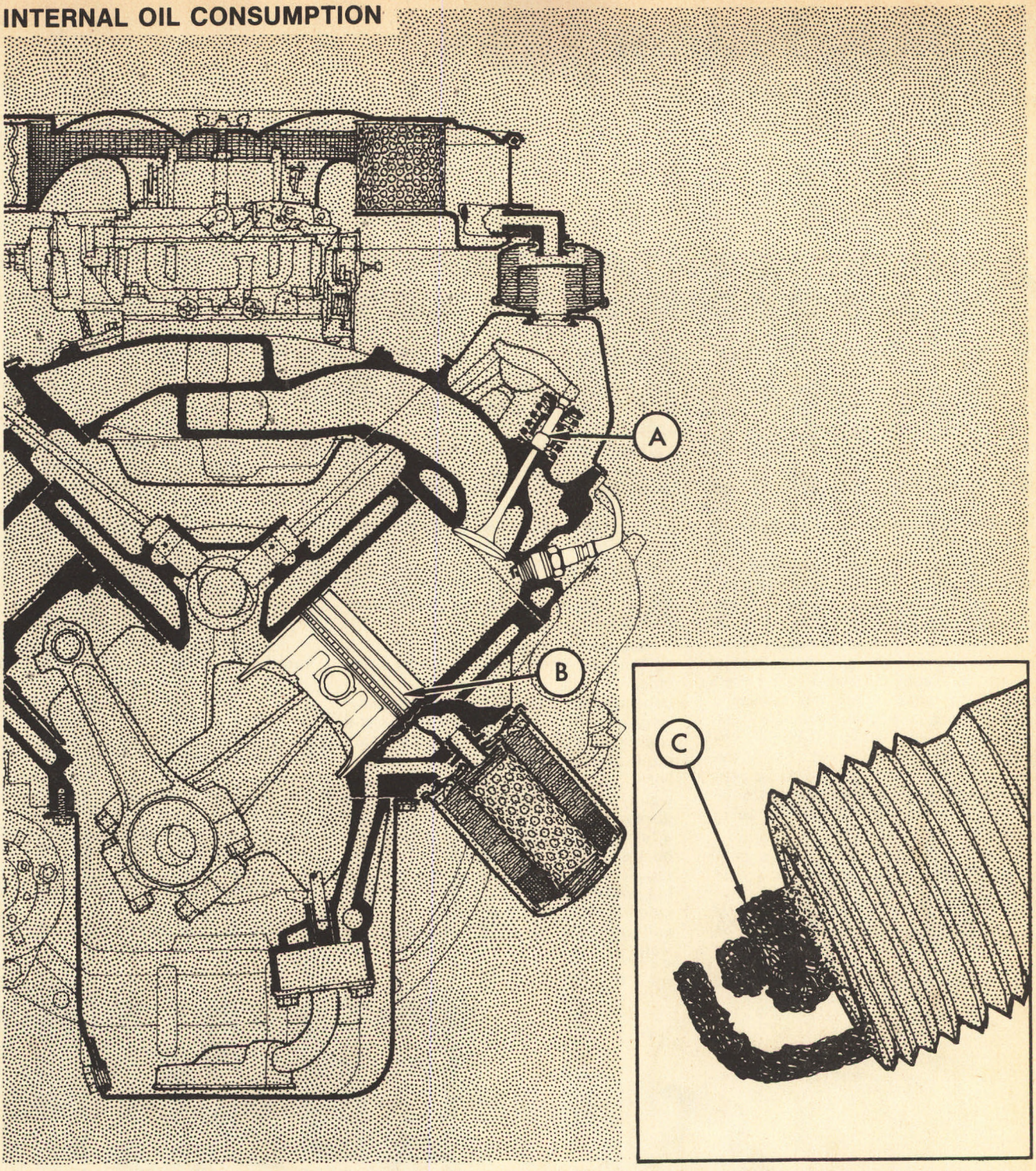
To check the vacuum booster pump, turn the windshield wipers on (with the engine idling).

CAUTION: BE SURE TO WET THE WINDSHIELD TO PREVENT DAMAGING THE WIPER BLADES OR SCRATCHING THE GLASS.

If the windshield wipers stop when you accelerate the engine, the booster pump is probably bad.

To confirm this, disconnect the line running from the pump to the intake manifold (B). If there is any oil film present inside the line, the pump is bad. Refer to the shop manual for instructions on how to repair or replace the pump.

INTERNAL OIL CONSUMPTION



Internal oil consumption means oil is being burned along with the fuel inside the combustion chambers of the engine. A sign of this is a blue, smoky exhaust, especially after the engine has been idling for a few minutes and then accelerates. Another symptom is fouled spark plugs (C), where a black, gummy substance is on the plugs. The positive crankcase ventilation system and the vacuum booster pump (already discussed) can show much the same symptoms, but the effect is much more pronounced in the case of bad engine wear.

The two primary places where oil can get into the combustion chambers are the valve guides (A) and the piston rings (B). The rings and the valve guides act as oil seals. As wear occurs, they begin letting some oil slip by into the combustion chamber, where it burns.

If internal oil consumption becomes severe enough, the engine will require a teardown and overhaul to replace and repair the valve guides and piston rings. Other possible problems are extreme bore wear along with the rings. If you suspect internal oil consumption, refer to the shop manual for overhaul instructions.

Cooling System

Although we often describe automotive engines as being either air-cooled or liquid-cooled, all are cooled by air in the final analysis. The use of a circulating coolant fluid is nothing more than an added step that transfers excess heat caused by combustion to a point outside the engine where it can be dissipated. So why use this secondary step? Why not just design all auto engines to be air-cooled? Good question—it's true that air-cooled engines are efficient and dependable; they warm up more quickly than the liquid-cooled variety and run at a slightly higher temperature.

But when you consider today's engine requirements, air cooling is impractical for most, and impossible for many. Such a system requires deep cooling fins on the block and head to draw the heat from the combustion chambers, and a fan to force cool air across the finned area. To a large extent, this necessity tends to dictate engine design and so becomes self-restricting. Air-cooled engines currently in use (most notably the VW and Corvair) are referred to as pancake designs, as cylinders are horizontal and semi-independent instead of being grouped in a vertical block.

Enclosing the basic engine in a container or water jacket filled with a fluid (usually water) that will absorb the excess heat is the most common type of automotive engine cooling. This is done by casting passages into the engine block allowing the water to circulate around cylinder walls, valve seats, valve guides, the combustion chamber top and wherever else heat must be removed. As some spots in an engine may run hotter than others, it's common practice to include deflection guides in the passages and distribution tubes or water nozzles to direct water to potential dead or hot spots.

There's a limit to how much heat water can absorb before it begins to boil away, and so it has to be circulated constantly. As the water in the jacket is heated, it must be moved outside the engine to a place where it can cool. In a liquid-cooled system, that place is the radiator and there are two methods of moving the water—natural and forced circulation.

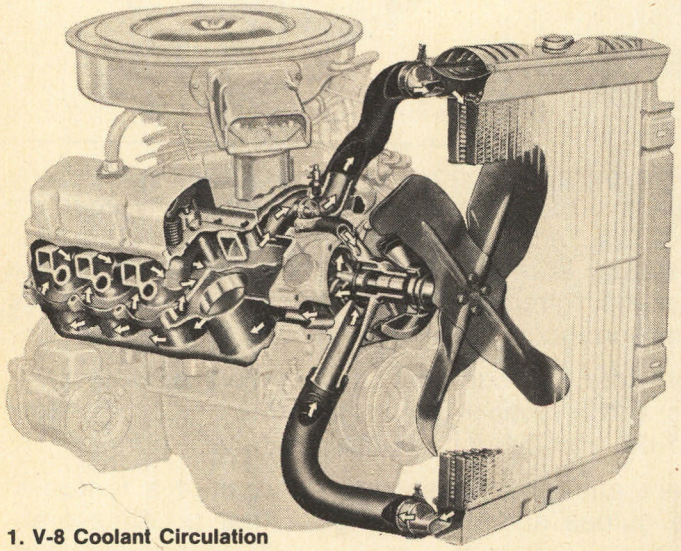
Natural circulation, or thermosiphon, is no longer commonly used—today's engines are too large and run too hot to depend upon water expansion for circulation. Briefly, it works like this: As the water surrounding the cylinders heats up, it expands. Like hot air, hot water is lighter; as it rises, the heavier and cooler water from the bottom of the radiator displaces it. The hot water goes through a hose to the radiator where it becomes heavier again as it cools and sinks to the radiator bottom, exerting pressure on the hot water presently surrounding the cylinders. This action is a continuous cycle and the hotter the engine, the faster the water circulates, maintaining fairly constant cylinder wall temperatures, as long as the engine is a low-output, low-compression design. In a modern engine with increased horsepower output, thermosiphon won't do the job.

Forced circulation, a much more dependable method, uses a belt-driven pump mounted at the front of the cylinder block. The pump is simply a housing with an inlet and outlet for water travel and an impeller, or flat plate with a number of blades or vanes, mounted on the pump shaft. As the pump impeller rotates, it pushes cool water into the cylinder block that forces the hotter water out. The faster the engine runs, the faster the water pump works.

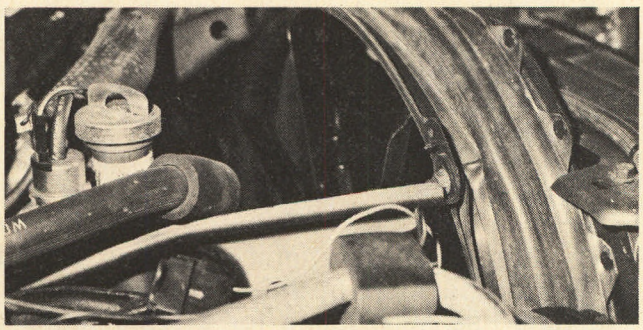
RADIATOR DESIGN

The hot water is pumped into the radiator, a tank-like device used to bring a large amount of hot water in contact with a large amount of cool air to let the heat transfer from water to air. Forced into the radiator's upper tank, the hot water cools as it filters down through tiny copper tubes in the core (copper is an excellent conductor of heat) and into the lower tank where it returns to the engine block. Most radiators are made of copper and brass, but some models of Corvette have an aluminum radiator. While there are five basic types of core construction, tube-fin and ribbon-cellular are most often used today.

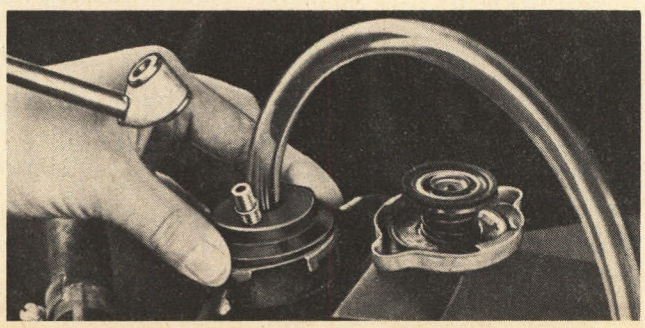
Obviously, the greater the distance between the upper and lower tank, the



1. V-8 Coolant Circulation



2. Oldsmobile Fan Shroud



3. Vega Coolant Siphon

Cooling System Capacity in Quarts	"Prestone" Brand Anti-Freeze Coolant Required (in Quarts)											
	2	3	4	5	6	7	8	9	10	11	12	13
5	−12°	−62°										
6	0°	−34°										
7	6°	−17°	−54°									
8	10°	− 7°	−34°	−69°								
9		0°	−21°	−50°								
10		4°	−12°	−34°	−62°							
11		8°	− 6°	−23°	−47°							
12		10°	0°	−15°	−34°	−57°						
13			3°	− 9°	−25°	−45°	−66°					
14			6°	− 5°	−17°	−34°	−54°					
15			8°	0°	−12°	−26°	−43°	−62°				
16			10°	2°	− 7°	−19°	−34°	−52°				
17				5°	− 4°	−14°	−27°	−42°	−58°			
18				7°	0°	−10°	−21°	−34°	−50°	−65°		
19				9°	2°	− 7°	−16°	−28°	−42°	−56°		
20				10°	4°	− 3°	−12°	−22°	−34°	−48°	−62°	
21					6°	0°	− 9°	−17°	−28°	−41°	−54°	−68°
22					8°	2°	− 6°	−14°	−23°	−34°	−47°	−59°
23					9°	4°	− 3°	−10°	−19°	−29°	−40°	−52°
24					10°	5°	0°	− 7°	−15°	−24°	−34°	−46°

4. Coolant Chart

greater the cooling effect that takes place in the core. But the low-silhouette designs of recent years required that the vertical core be redesigned and so today, the crossflow or transverse core is popular. This amounts to tipping the radiator on its side, with the top and bottom tanks becoming side tanks and water flowing horizontally instead of vertically. In many transverse designs, the water pump pumps into the "bottom" tank (the one without the radiator cap). The result is reduced pressure against the cap, allowing the temperature to rise higher before the cap blows. "Blowing the cap" on a vertical tube radiator is common whenever the tubes get clogged with rust or scale. The water can't get down through the tubes, so it goes out through the cap. Changing the cap won't help, because there's nothing wrong with it. The only remedy is to clean out, boil out, or rod out the tubes, depending on how bad they are.

In a transverse core radiator, plugged tubes will slow down the circulation and may cause overheating, but they will not cause the cap to blow and lose water because the water pump is exerting pressure on the "bottom" tank. There have even been some vertical designs that pumped into the bottom tank (notably Pontiac), but they aren't common.

1. Coolant circulation is a simple but essential system to proper operation of an engine. Any blockage in the path of the arrows will cause overheating, possible damage.

2. Fan shrouds come and fan shrouds go, but Oldsmobile's Venturi Ring is the most sophisticated yet. The ring only clears the tips of the fan blades by 2/10-in., which makes the fan more efficient. In order to maintain the blade tip clearance, the venturi ring is mounted on the engine, with a flexible rubber seal between the ring and the radiator shroud.

3. In case you hadn't noticed, the Chevy Vegas coming out now do not have any coolant drains. The only way to change the coolant is to siphon it out. Easiest way is with Thexton's new Syphone-Aire, which uses air or mouth pressure to start the siphoning action.

4. Cooling system capacity can be found in your owner's manual, and then with this chart you can add antifreeze to protect to the lowest expected temperature.

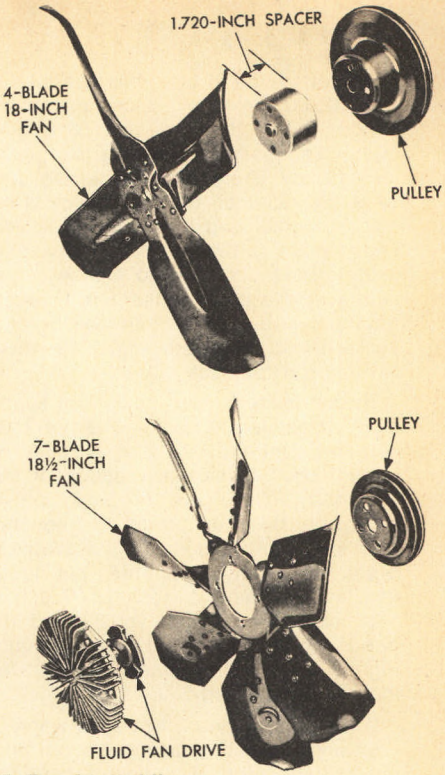
5. The same cars often have different fan assemblies. Make sure you replace with fan of your model.

FAN DESIGN

To increase the radiator's cooling action, a fan mounted on the water pump shaft and driven by the same belt draws air through the radiator core. There are several types in use: the fixed fan that rotates constantly with the pump shaft; a thermostatic fan that slows down when cooling is not needed; a centrifugal fan that reduces its speed at high engine rpm; a fluid coupling fan that adjusts its speed to driving conditions; a flexible blade fan that reduces pitch at higher speeds for easier turning, etc. As any fan requires engine power to rotate, these latter types reduce drag on the engine and so increase available horsepower. If radiator placement is too far from the fan, a sheetmetal shroud is used to prevent recirculation of the same air, thereby increasing the fan's efficiency. Blade number and arrangement differ depending upon requirements.

CAPS AND PRESSURE

Pressurizing a radiator system improves its cooling efficiency and prevents evaporation and surge losses. The pressure cap increases air pressure in the system by several pounds per square inch, allowing water to be circulated at higher temperatures without boiling. With the greater difference between the water and outside air, heat passes from the water faster. A pressure cap contains a blowoff valve and a vacuum valve and seats tightly over both the filler mouth and its edges. A calibrated spring in the blowoff valve holds the valve closed, producing pressure in the system. If the pressure exceeds the amount for which the system was designed, the valve blows off its seat, relieving the excess. When the engine has been shut off and cools down, a vacuum might form, dropping the inside pressure sufficiently to let outside air pressure collapse it. If a vacuum does start to form, the vacuum valve opens to let air into the system before damage is done.



5. Fan Assemblies

Many cooling systems now use a coolant recovery system in conjunction with the radiator. This small additional tank provides room for its expansion. It eliminates loss of coolant when the engine is turned off and "boils over." The pressure cap used on a radiator with a recovery system must have a gravity-operated vacuum valve. If the vacuum valve is spring-loaded, it must hang open or it will prevent the flowback of coolant to the radiator.

ANTIFREEZE

Up to this point, we've referred to coolant and water as one and the same, but ordinary water is no longer recommended and seldom used today except in emergencies. Antifreeze solutions with an ethylene glycol base have replaced the use of plain water. When mixed proportionately with water, they provide protection from freezing temperatures and prevent a cracked engine block. They also contain additives to combat corrosion and neutralize rust formed in the engine block before it can plug the radiator core.

For best corrosion resistance and rust prevention, a 50% solution of antifreeze and water should be used. This will raise the boiling point at sea level to 227° F.; 15° higher than plain water. And a 50% solution will lower the freezing point to -34° F. That is much lower than most areas need, but the 50% solution should be maintained even in hot climates because of its corrosion protection.

Glycol is more expensive initially, but it doesn't boil away, and it's a good water pump lubricant. However, if you have a leaking head gasket, a cracked block or cylinder head, the glycol will pass into the oil, and contaminate it very quickly.

Cooling System

If it's not caught in time, this can lead to a locked-up engine, since glycol will congeal when it mixes with oil and in doing so, completely plug oil pump screens, oil filters and oil passages. A white discoloration on the dipstick is the danger signal, and the most convenient check point is the oil filter. If the filter sludge looks like curdled milk and molasses, you've got troubles, but it's worth attempting an oil flush before bracing yourself for a complete engine teardown to clean up the mess.

Hustle down to your local paint supply store or wholesale dealer and purchase a quantity of butyl "Cellosolve." A retardant used to slow the action of solvent, butyl "Cellosolve" is packaged on a regional basis according to frequency of use; in warm climates, it's available in 5-gal. or larger containers, but those who live in colder areas can find it in 1-qt. cans. How much you'll need depends upon your crankcase capacity. Figure adding two parts butyl "Cellosolve" to one part SAE 10 oil.

Drain the engine oil while it's warm. If your engine uses a disposable oil filter, leave it in place; if it has a cartridge filter, remove the filter and replace the empty can. Fill the engine with the mixture then start it up and run at fast idle, watching the oil pressure and operating temperature carefully during this time. The oil pressure should read normal and operating temperature must remain above 150° F.

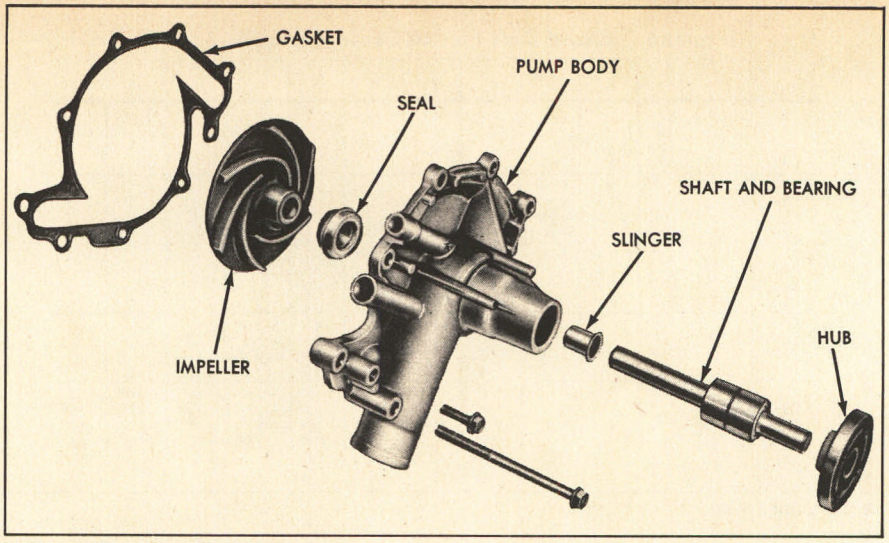
Stop the engine after approximately 45 mins. to 1 hr. and drain the crankcase. If the contamination was really severe, it may be necessary to repeat the operation more than once to completely dissolve the sludge. After you're satisfied that the sludge is gone, refill the engine with a flushing oil or fresh 10W oil and run at fast idle for another 10-15 mins. Drain the flush oil and then replace the disposable oil filter with a new one, or insert a clean cartridge into the can, and refill the crankcase with the oil you'd normally use. Having saved the engine from total disaster, all you have to do now is find the leak and correct it before driving the car again.

It may be possible to free a "seized" engine by circulating hot water of at least 140° F. through the cooling system. Attach a hose from a hot water source to a nipple installed in a core plug hole, then allow the water to flow through the engine and out through the radiator fill neck. If the engine will turn over on the starter, follow the steps outlined above with butyl "Cellosolve."

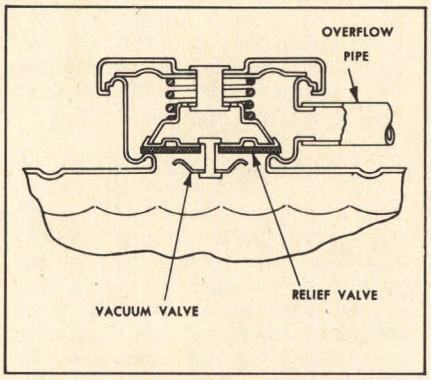
If the engine doesn't turn over, remove the spark plugs and pour undiluted butyl "Cellosolve" through each hole until the pistons are covered. Wait about 15 mins., then jump on the starter again. Let it spin until the mixture has been pumped out through the plug holes. Now, replace the plugs and, again, follow the steps indicated above with butyl "Cellosolve."

Anti-leak antifreezes have been on the market since about 1969. Some people feel that there is a danger of plugging up the cooling system, that perhaps anti-leak really means anti-flow. Such fears are groundless. In the few cases where plugging has occurred, the cooling system was on its last legs, with rust-clogged passages that probably would have plugged up anyway the first time the car hit a good bump and shifted the sediment around. The cooling system should never be drained and new antifreeze dumped in unless you flush it out. And it's a good idea to use flushing chemicals, too.

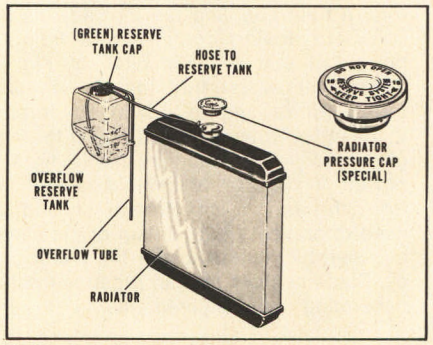
In 1972, Prestone announced a new antifreeze called Prestone II. It has a new formulation for better engine protection and without any anti-leak properties. So those of you who didn't feel quite comfortable with the anti-leak formulas can now head for your nearest Prestone dealer. If you like anti-leak, look for du-Pont or Dow brands.



1. Pump Components



2. Vacuum Valve



3. Coolant Reserve System

1. Water pumps should be replaced as a unit, but an understanding of how they are constructed can help when you try to diagnose problems

2. This type of cap is open to the atmosphere until the rush of air or coolant trying to escape closes the vacuum valve. A cap like this is easier on the radiator because the system is only under pressure part of the time. Other types have a spring on the vacuum valve, which does not allow any pressure to escape. Spring-type vacuum valves will not work with a coolant recovery system. Use the open type.

3. Coolant reserve systems, such as this '73 Dodge version, prevent the loss of radiator coolant. Special pressure cap allows coolant to overflow into plastic reserve tank. When engine cools, pressure differences between tank and radiator cause coolant to flow back into radiator.

4. This pressure tester will determine if there are internal leaks in the cooling system.

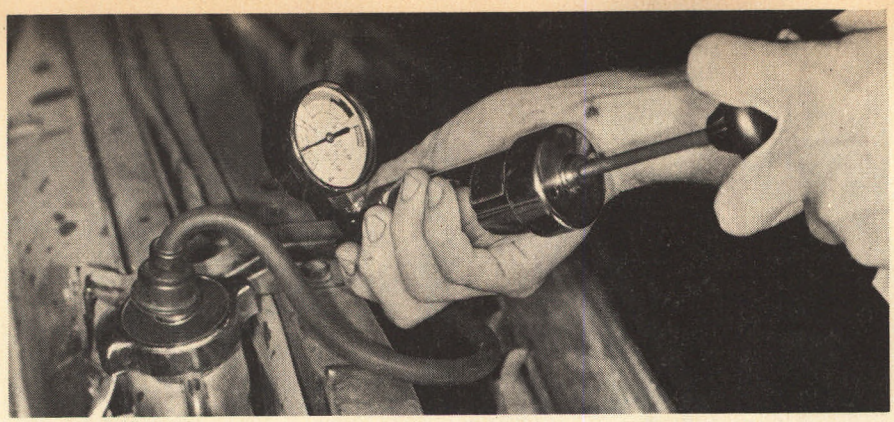
5. Add an adapter and you can also test the cap. This one's a dud.

6. Three types of intercoolers. Fitted into the radiator's bottom tank, they allow automatic transmission fluid to circulate for cooling, preventing transmission overheating.

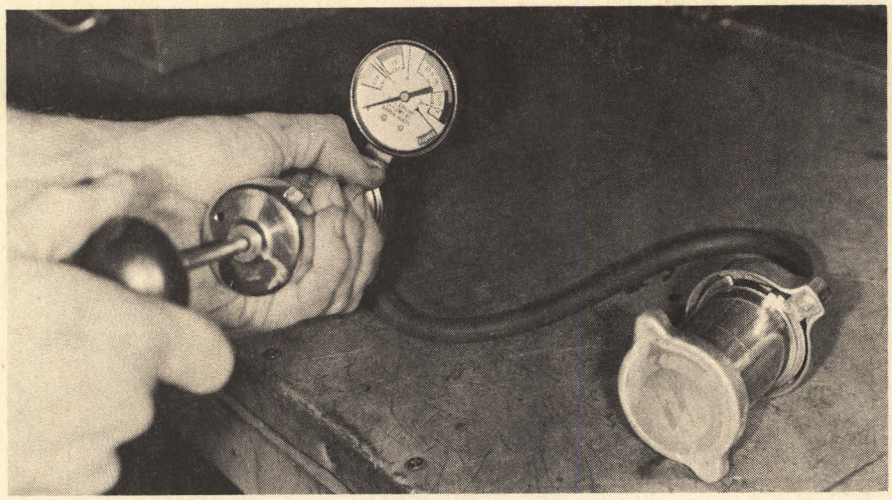
7. Service stations usually have a Bloc-Chek kit. This simple test for exhaust gas leakage involves a change of fluid color if gas is present.

RUNNING PURE WATER

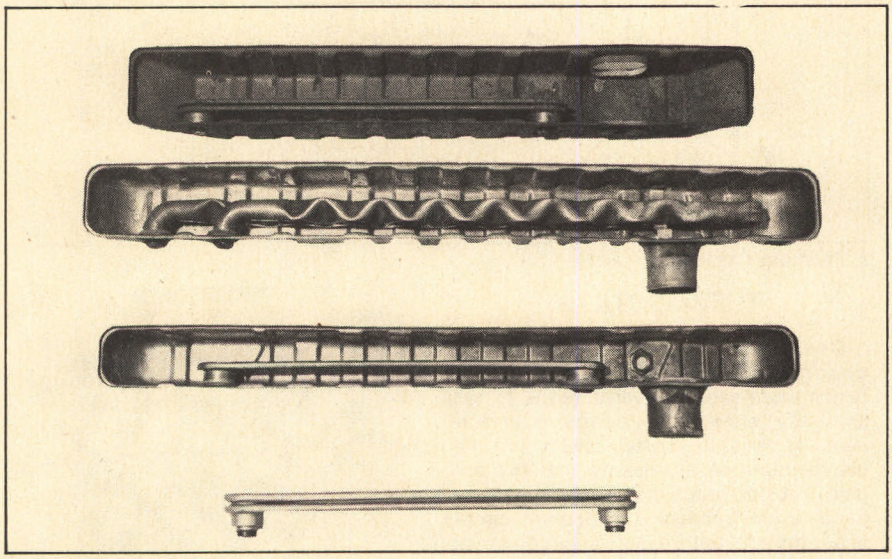
In older cars, you could run pure water with a rust inhibitor and not hurt a thing. Don't try this on a late-model car, because your hot indicator warning light will not work with pure water. Here's why. New cars recently came from the factory in most cases with a 33% antifreeze solution and a 14-lb. pressure cap. With this combination, the coolant will boil at approximately 256° F. Temperatures in the 250° range may seem awfully hot, but they won't hurt the engine as long as the coolant doesn't boil.



4. Pressure Testing



5. Cap Pressure Check

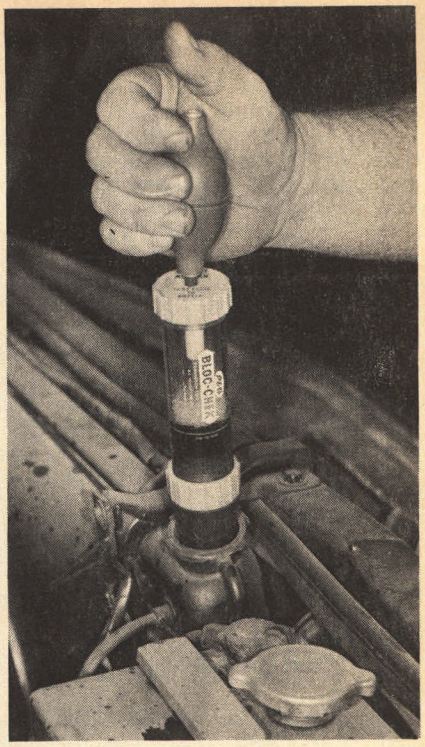


6. Intercoolers

With no danger present at the lower temperatures, the engineers designed the warning light to come on at about 256° F. If you run pure water, it will boil at 247° with the factory 14-lb. cap. Thus, with pure water your engine could be boiling, sustaining a lot of damage from uneven cooling, and the hot warning light would never come on. For proper warning light operation, you must run at least a 33% antifreeze solution, and 50% is even better. New cars are now coming off the end of the assembly line with 44-55% antifreeze. Your owner's manual will tell you how much you should have. If not, stick with the 50% solution.

COOLANT ADDITIVES

There are many chemical compounds and additives on the market designed to give last-minute hope to the unfortunate soul facing a major radiator repair job. These chemicals range from pellets to be dropped in the radiator to fluids designed to dissolve rust or stop radiator leaks. Use of these products inevitably guarantees that the repair will have to be done anyway, but buying a $3.00 can appeals to the innocent who is otherwise faced with a large repair bill, and he figures it's worth the gamble. Radiator shops will tell you that stop-leak products are really one of their most dependable business builders, followed closely by the anti-rust solutions. However, many new cars come from the factory with some kind of anti-leak chemical in the cooling system. The difference is that the factory knows exactly how much to put in. They don't just dump a lot of goop in that will plug everything up.



7. Exhaust Gas Check

If the leak is a minor one, the stop-leak solution may work temporarily, but most drivers then put off the inevitable repair and that's where they make their mistake. Remember, the radiator is made of brass and copper and these metals don't rust—they corrode. Corrosion is a chemical process that is self-accelerating in nature and once it starts, the affected area must be completely cleaned to stop it.

Any rust found in the coolant comes from the engine's water jacket and can settle in the tiny radiator tube passages, blocking coolant flow. So you're actually faced with two different problems that using chemicals to solve will only aggravate. Anti-rust solutions will actually free rust that has accumulated in the water jacket passages and let it circulate into the radiator; stop-leak solutions will plug minor holes that corrosion continues to enlarge.

But if you have one of the 1973 Hornets without air conditioning, it's probably fitted with an aluminum fin radiator; check before you add anything to the cooling system. These are identified by two decals containing warning and repair information. Hot water or steam are the only cleaning agents to use, as anything caustic will eat holes in it faster than moths in a wool factory. Repairs should be done only with Alcoa Flux #64, 30/70 or 40/60 tin-lead solder and a minimum of heat.

So what's the answer? Simple—change the coolant at regular intervals. All major brands of antifreeze contain additives to

prevent radiator corrosion and the formation of rust in the block, but these additives wear out long before the antifreeze itself. Change the coolant once a year and save yourself a lot of headaches. If you're old-fashioned and still insist on running water during the summer months, be sure to use anti-corrosion and rust inhibitor additives with it or you'll defeat everything that antifreeze has done for your cooling system.

The new super cooling additives are another controversy. They are supposed to transfer heat better than any antifreeze, and thereby keep the engine cooler. Prestone engineers tell us that they have never found a chemical on the market that will increase the heat transfer any better than antifreeze. And in some cases the super cooling additives will affect the anti-foaming properties of the antifreeze, thus giving less efficient cooling.

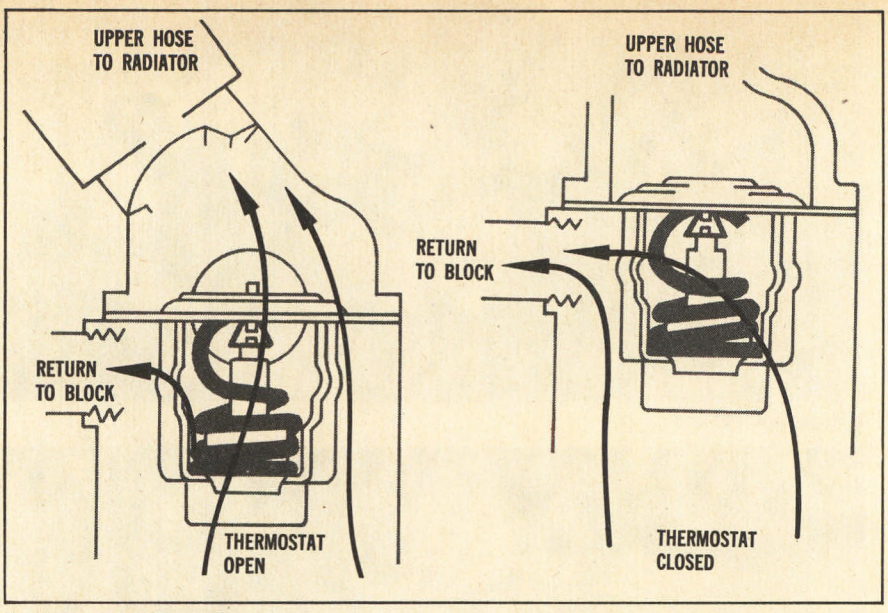
FINDING LEAKS

One source of damaging corrosion comes from exhaust gas leaking into the cooling system. The strong acids in the gas combine with the water in the coolant and eat away at the radiator tubes.

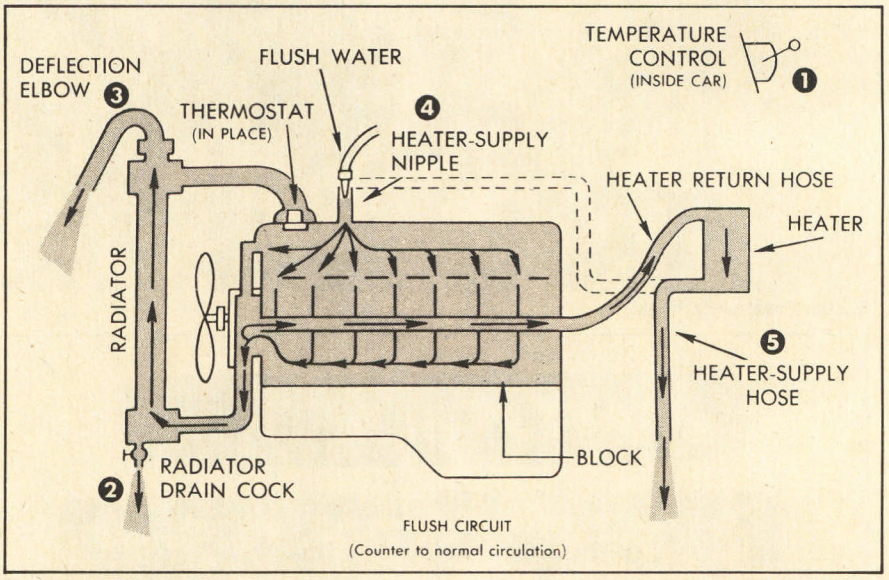
You can also check exhaust gas leakage by using a block check kit. Insert the block check tool into the radiator filler neck and hold just above the coolant level. Squeeze the bulb and fill with air. If the tool fluid changes from its normal blue to a transparent yellow, exhaust gas is present. By running the engine with the spark plugs grounded on one bank at a time, you can determine which head gasket is at fault on a V-8 engine. An equally simple way is to disconnect the upper hose, drain the radiator until the coolant is just above the cylinder head and remove both thermostat and fan belt. Start the engine and accelerate rapidly a few times. If exhaust gas is leaking, the coolant level should rise considerably, and bubbles will appear.

Water leaks in the cooling system will cause a loss of pressure and can lead to serious problems. To check for a water leak, top up the radiator to about ½-in. of the filler neck and run the engine until it's at operating temperature. Then attach a pressure tester in place of the cap and apply 15 psi pressure. If it holds steady, there's no leak, but a pressure drop tells you to check the hose connections, water pump, radiator and engine expansion plugs for an external leak. If the pressure tester needle fluctuates, you've got an exhaust gas leak that should be checked out. Pressure caps can also fail and should be checked with the same tester. If your cap won't hold the rated pressure, replace it with a new one of the proper rating.

Some radiators contain special tubing in the bottom tank that acts as an intercooler or heat exchanger. Automatic transmission fluid flows through this intercooler and prevents the transmission from overheating. An intercooler leak not only affects your cooling system's performance but can spell transmission problems if it's not taken care of.



1. Thermostat Operation

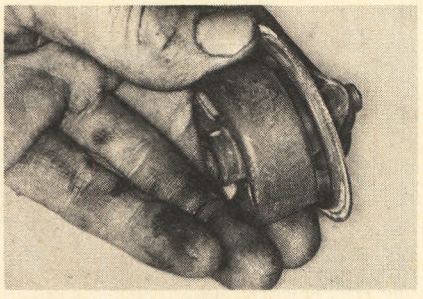


2. Flushing Coolant

THERMOSTATS

Check the thermostat when you change the coolant. This simple temperature-sensitive valve tends to fail gradually, either from corrosion or foreign matter. Thermostat failure (or the use of none at all) means that the engine will not reach its proper operating temperature because the coolant circulates through both it and the radiator at all times. Operation below proper temperatures results in premature engine wear. The heater also works very inefficiently, if at all, a condition easily noticed during cold winter months, but not necessarily in the summer. Unscrewing the cap screws holding its housing lets you reach the thermostat easily. The housing is usually found at the point where the outlet hose is attached to the engine. Avoid a mess by draining the coolant below the housing level before loosening the bolts.

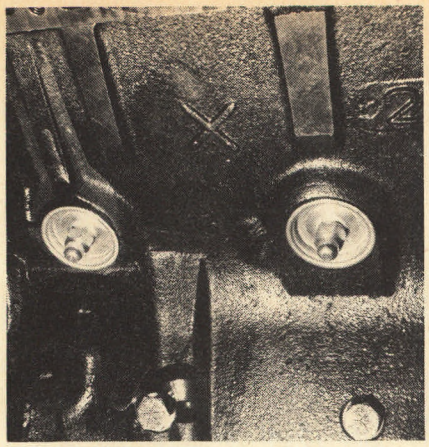
Thermostats are marked with their designated opening point (usually 180° through 205° F.) and you should always use the exact one specified for your engine. To test your old thermostat or even



3. Stuck Thermostat

a new one (brand new is no guarantee that it will work), rig up a simple apparatus and borrow the kitchen stove. You'll need a water container, preferably Pyrex or equivalent so you can see better, a household cooking thermometer that reads up to 250° or so, a wire hook to suspend the thermostat, a feeler gauge and a piece of string. Insert the feeler gauge between the valve and its seat and attach the string to the gauge.

You'll need the temperature figures for both the initial and fully opened positions. These are available from your dealer or wherever you buy the new



4. Bolt-in Core Plugs

6. Thermostat Bleed Hole

1. Replacement is the only cure for a faulty thermostat. Always check the specs for your engine, since the old unit may have failed because it was the wrong one.

2. Prestone recommends this method of flushing the cooling system. Note accessory deflector in radiator neck.

3. This thermostat is stuck open—but instead of causing cold running, it actually caused overheating, because it was stuck half-way open and didn't allow enough coolant to pass through the system.

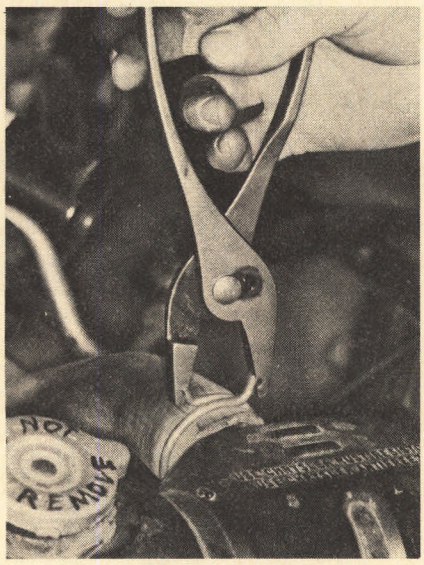
4. Bolt-in core plugs are a cinch to install, and to remove if necessary. Some types of block heating elements are inserted in these holes.

5. If you suspect that your dash's temp gauge or light isn't honest, you can check the actual, warmed-up temperature of your radiator water with a high-range thermometer. Most radiator shops will have one and should be glad to check it for you.

6. A thermostat must seal tightly if it is going to give a quick engine warm-up. We have found samples of this particular design of thermostat that allowed enough of a gap when they were closed to give the engine an inordinately long warm-up time. All thermostats have bleed holes to enable air trapped in the block to escape (arrow).

7. Sometimes it's a tricky job to remove spring-type radiator hose clamps. These special pliers make clamp removal a simple, easy chore.

5. Checking Radiator Temperature



7. Spring-Type Hose Clamp

thermostat. It must not touch any surface while being heated and the water should be stirred gently to ensure even distribution of the heat. A typical set of specs for a 195° thermostat is that a .003-in. gauge should slip free within +3° of the rating and the valve should be fully open at 218° F. To replace the thermostat, let it rest in position with the longer or valve end toward the engine, then refasten the housing. You'll need a new housing gasket which can be purchased ready-cut from a dealership or made at home from ordinary cork gasket stock. The mating surfaces should be clean and the gasket coated with cooling system sealant. The hose is reattached using a screw-type attaching clamp.

FLUSHING PROCEDURES

The average car owner's idea of flushing consists of opening the petcock on the radiator bottom and maybe the two on each side of the engine block (the Vega has none and must be siphoned), sticking a garden hose in the radiator and letting the water flow. Unfortunately, this accomplishes very little. Outside faucets are normally connected only to cold water, so sticking the hose into the radiator filler opening and waiting until the water from the drain cock appears to be clear flushes only the radiator. The cold water keeps the thermostat leading to the engine cooling passages closed and even if the engine drains are open in this procedure, there's incomplete circulation, with residue from old dirty coolant remaining in the engine. The following step-by-step procedure is basic to an effective annual coolant change.

1) Set heater temperature control to "high." If your car is equipped with a vacuum-operated heater valve (check with your dealer—this is found mainly on newer cars with factory air conditioning), run the engine at idle during all flushing procedures described, as a vacuum valve will only stay open with the engine running. Keep a close watch on the engine temperature gauge.

2) Open radiator drain cock and let radiator drain. Do not open engine drain cocks.

3) Remove radiator cap and put a deflection elbow in the filler neck to prevent excessive splash into the engine compartment.

4) Remove hose from heater supply nipple at the engine block. Point this hose downward for drain.

5) Connect water supply to the heater supply nipple at the engine block. This does not have to be a positive connection; an ordinary garden hose will do as long as most of the water can be directed into the engine.

6) Turn on the water, make sure it is cold and flush for 3 to 5 mins. without the engine running, unless you have a vacuum valve. Squeeze the outlet or upper radiator hose during the last minute of flushing to remove any trapped liquid.

7) Turn off water and close radiator petcock. Reconnect heater supply hose to its nipple and remove deflection elbow from radiator. Be sure the system is normally full of coolant.

CORE PLUGS

Every engine has at least seven "freeze" or core plugs—three on each side of the block and one in the back. These are filled with metal, but it's softer and thinner than the block material. If the coolant freezes, the expanding fluid pushes out the plugs, sometimes preventing block damage but not always. Core plugs are subject to corrosion and can develop small leaks. Most are a simple press fit and can be removed if faulty by drilling a hole in the center and prying out with a screwdriver. Drain the block before starting work and take care not to let pieces of the plug fall into the coolant passage. The same press-in replacement type can be used but bolt-in plugs are easier to seat and remove. These use a toggle bolt that slips into the water jacket, with the plug bolting up with a gasket or O-ring between itself and the block.

HOSE REPLACEMENT

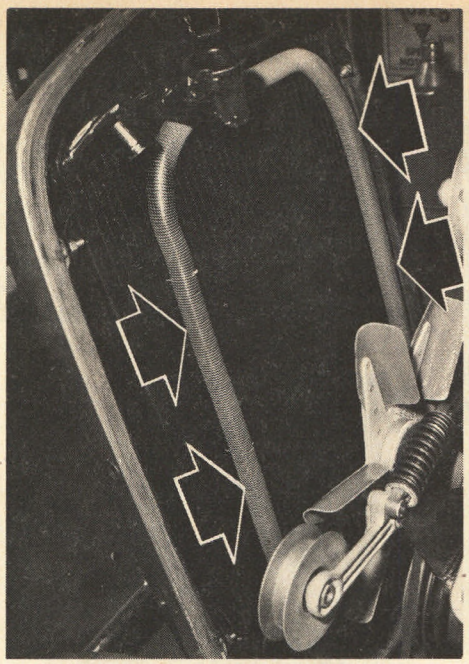
You can sometimes tell how good a hose is by its appearance and feel, but many hoses have a spiral wire reinforcement inside, and this can rust and disintegrate without affecting the outside appearance. Squeeze the hose at midpoint and you should be able to feel the wire; if not, replace the hose. Unfasten the hose clamp, then twist as you pull the hose off. Stubborn hoses may have to be cut off with a knife. Apply a dab of sealing compound around the connecting nipple and fit the new hose over it.

Cooling System

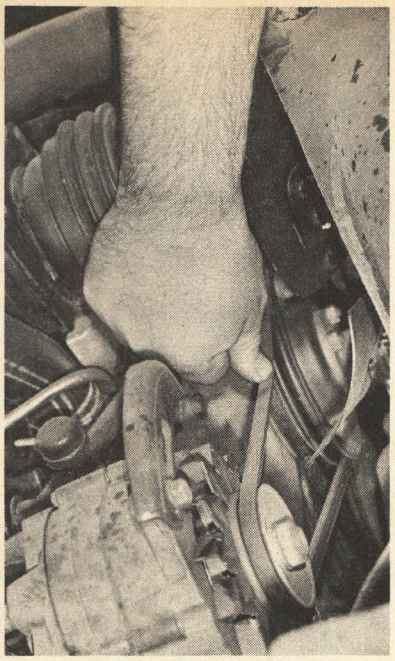
Use screw-type clamps for replacement, as spring-type clamps may leak.

FAN BELTS

Fan belt tension should be checked periodically. Low tension means belt slippage, which will wear out the belt, let the battery run down and cause the engine to overheat. Too much tension overloads the water pump and wears it out prematurely. Adjust by loosening the alternator mounting bolt and moving it toward or away from the engine block before retightening. If you don't have access to a belt tension tool, you can set it by this rule of thumb—belt deflection with your thumb pushing on it, should be about ¼ in. at the midpoint of its longest unsupported section. A loose belt wears out fast, but a tight belt wears out the bushing (or bearing) in the water pump. So, if you don't have a tension gauge, keep that belt a little loose. Belts are much cheaper to replace than pumps.

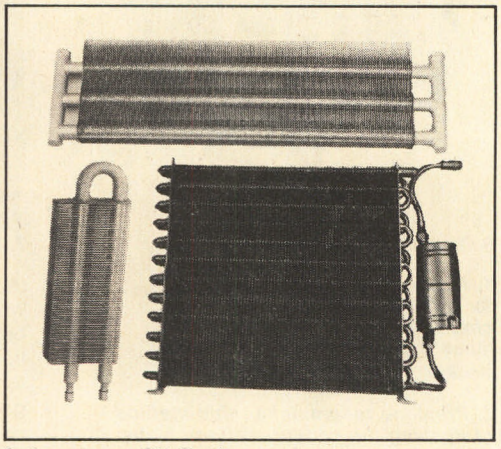


1. Auxiliary Flex-O-Kool



2. Belt Deflection

3. Types of Clamps



4. Accessory Oil Coolers

HOT RODDING THE COOLING SYSTEM

Remember, the manufacturer put no more radiator into your car when it was built than was considered adequate to handle the original engine under normal driving conditions. So if you do anything to significantly add horsepower or change to a larger engine, you should change radiators too. If you have a 1960 model or later, it's likely that there's a heavy-duty package available for it. This package will include the automatic transmission cooler, fan, and water pump with the radiator. But if you stuff a Hemi in a Plymouth Belvedere that came factory-equipped with a Slant-6, you'll have to add a radiator which the factory designed for use with the Hemi. Depending upon your car, this may or may not bolt right in, but there should be no great problem in the installation. Just secure it at the four corners, make sure the fan has proper clearance and connect a pair of universal hoses. Be sure to change the thermostat and pressure cap to conform to Hemi specs.

If the old radiator adequately protects against overheating, there's no point in putting in a larger one. And don't think of radiator "bigness" in terms of coolant capacity; the Model A Ford had a radiator twice the capacity of a current Mustang equipped with a 289-cu.-in. V-8. The differences are the improvement in pump efficiency and the pressurized system, not to mention that the fins are in a better cooling arrangement than the A's old cellular structure.

Eliminating the fan should be approached with caution. You can sometimes improve the engine efficiency if your driving doesn't involve much city traffic. In cases of marginal overheating caused by hopping up the engine, the shrouds used with air-conditioned cars will usually clip right into their non-air-conditioned counterparts. For more extreme modifications, where the shape of the radiator is important to achieve a desired styling effect, any competent radiator specialty shop can adapt almost any radiator to your needs, but this is expensive.

Take care when you buy a chrome-plated pressure cap; it must be designed to operate at the same pressure as the original. Radiator covers, which can be as simple as a window-shade-like arrangement pulled by a string from the dashboard, help warmup in extremely cold climates. Visual indicators for the coolant level are quite helpful in discouraging the service station attendant from opening the pressure cap. Filters are sold for cooling systems, but if they contain chemicals, they may not be compatible with the brand of antifreeze you use.

Radiators through the years have been made in different basic designs. The cellular is somewhat inefficient because it won't pass the water fast enough. Tubular is better, but the comparatively recent tube-fin design, in which the fins are made in accordion pleats between the tubes, is a tremendous improvement over the plain tubular core. Changing to a tube-fin core might even solve a hot rod cooling problem for you if you were trying to run a big engine in a small car that won't accommodate a large size radiator.

That's about all there is to a cooling system. Now if you can just stop service station attendants from removing your radiator cap when your engine is hot and allowing all of your antifreeze to burble out on the ground, you've got it made.

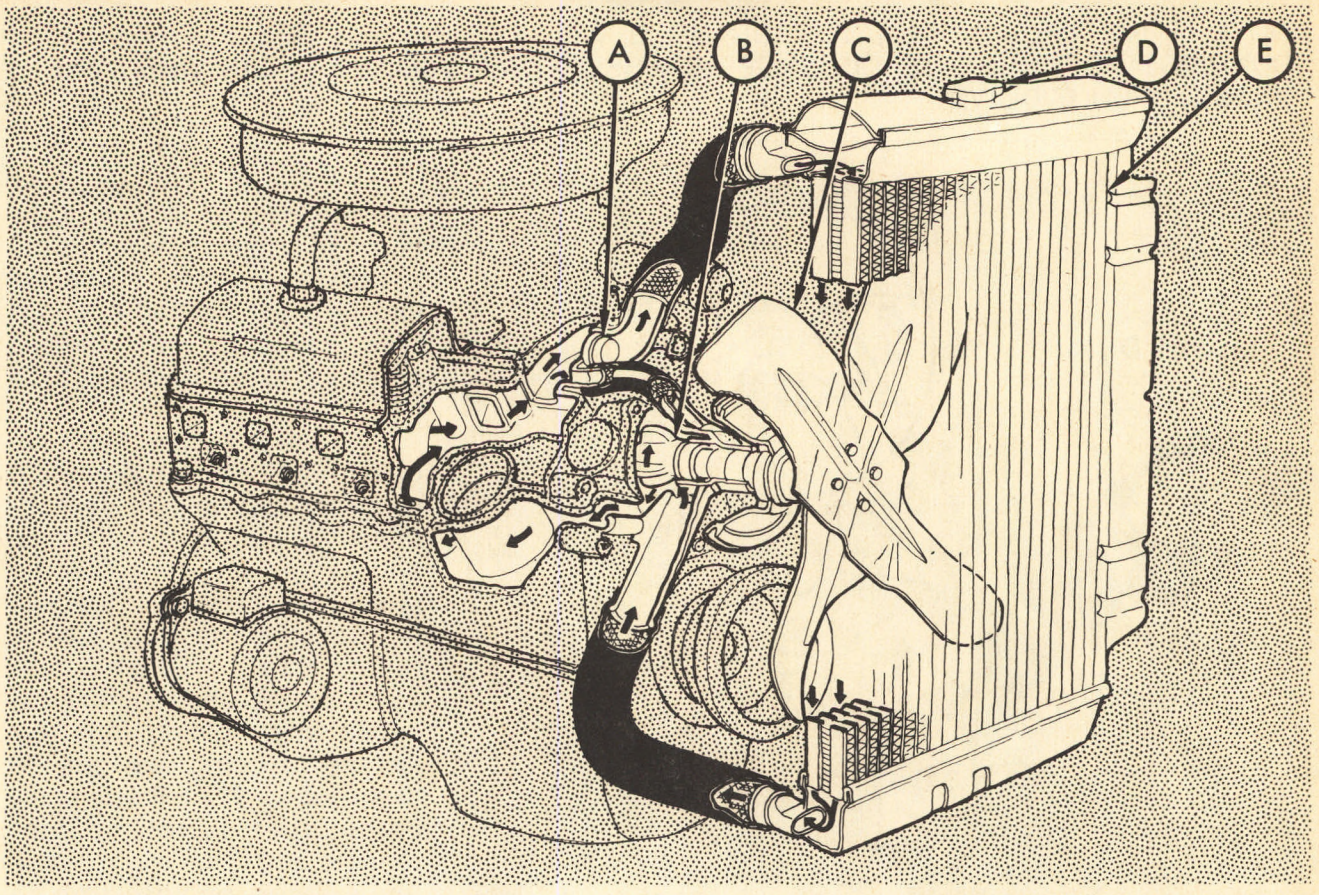
1. Easiest oil cooler to install is the Flex-O-Kool. Bend it to desired shape and wire it to radiator. We installed a Flex-O-Kool on a flathead Ford, it reduced temperatures, and decreased oil consumption. It's available from Car Care Parts, 6900 Valjean Ave., Van Nuys, Calif. 91406.

2. Set belt tension by rule of thumb. Quarter-inch deflection at midpoint saves belt as well as bushings.

3. The wire-type clamp on the left is often used by the factory, but does not seal very well when it gets old. Throw it away and use screw-type.

4. Accessory oil coolers come in all shapes and sizes. If placed where fan causes air blast, they will definitely keep temperature down.

TROUBLESHOOTING COOLING SYSTEMS



The parts of the engine cooling system are: the radiator (E), the radiator cap (D), the water pump and fan (B and C), the thermostat (A) and the hoses which connect the radiator to the engine. The water pump is driven by the same drive belt that turns the fan. Water is pumped from the bottom of the radiator into the engine by the water pump, circulated through internal passageways inside the engine block and heads to remove excess heat from the engine, then pumped out through the thermostat and upper radiator hose to the reservoir at the top of the radiator. The hot water then flows slowly down through a system of tiny tubes surrounded by fins. This is known as the radiator core. Heat is transferred from the water to the surrounding air by the fins. When the cooled water reaches the bottom of the radiator, it is again picked up by the pump and sent through the engine.

The fan assures a sufficient flow of air through the radiator fins when the car is stopped at idle or moving slowly. Without the fan to draw air over the radiator when the car is not moving fast enough for motion to do the job, the radiator would be unable to pass enough heat into the air, and the coolant would soon heat up.

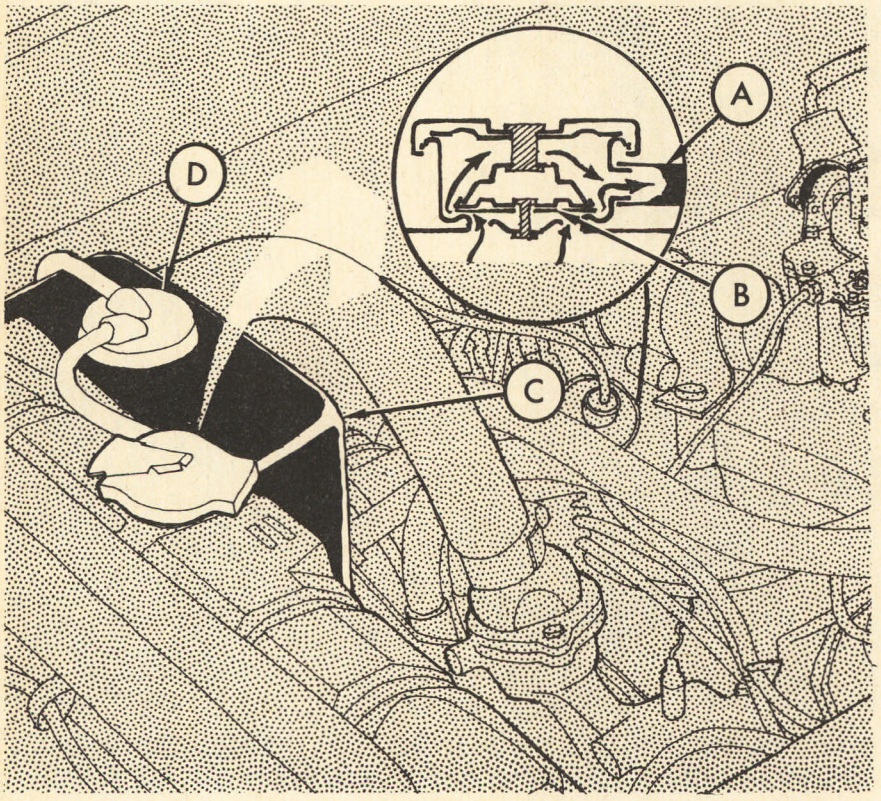
The major problem in cooling systems is the buildup of rust and scale inside the cooling system. This robs the system of the ability to conduct heat away from the engine (by plugging up the tiny tubes in the radiator and jamming the thermostat closed). Scale and corrosion can be reduced by the use of special coolant mixtures (antifreeze and water) which have chemicals to reduce or prevent this buildup.

In troubleshooting the cooling system, *check the obvious first.* A breakdown of the system usually shows up first as a loss of coolant. If the temperature warning light on the dashboard or the temperature gauge show a high temperature indication, check the level of the coolant in the radiator.

WARNING: USE EXTREME CARE WHEN CHECKING THE COOLANT LEVEL IN THE RADIATOR. LET THE ENGINE AND COOLING SYSTEM COOL DOWN TO A SAFE LEVEL (LUKEWARM TO THE TOUCH) BEFORE LOOSENING THE CAP. FAILURE TO DO SO CAN RESULT IN SEVERE BURNS FROM HOT LIQUID.

If the coolant level is down, visually check the hoses and radiator for leaks or rust marks which might indicate the presence of leaks.

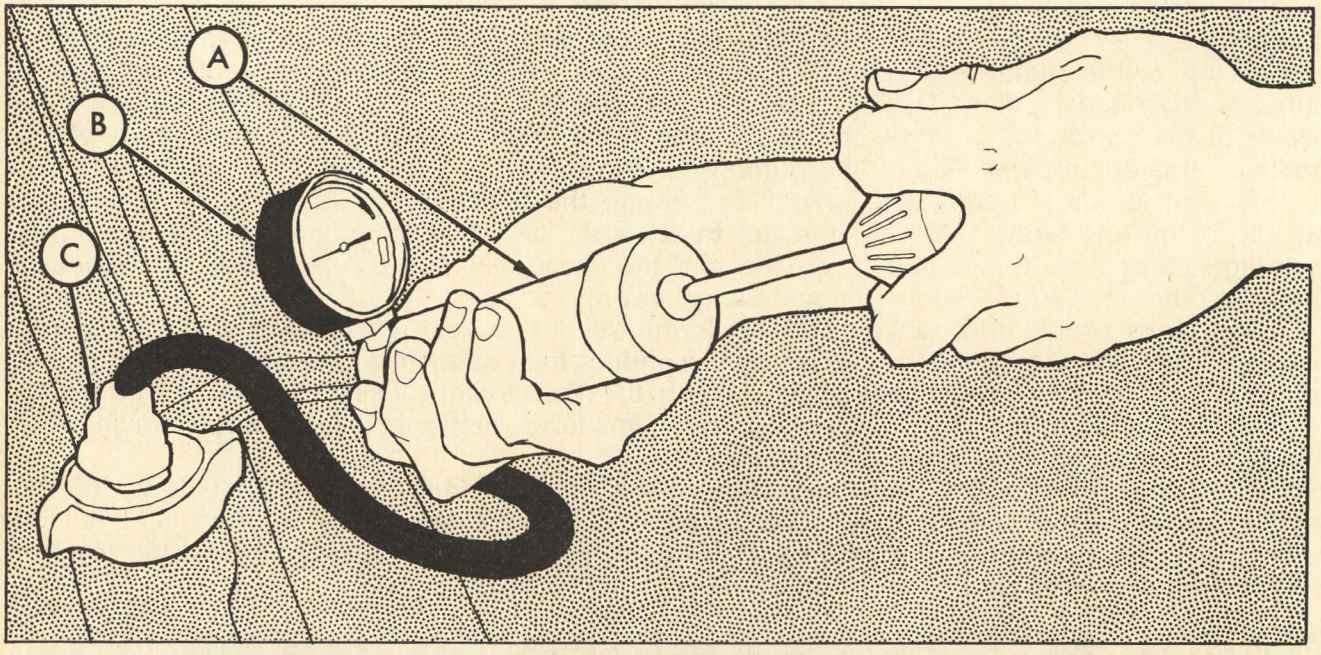
NOTE: SOMETIMES A RADIATOR OR HOSE WILL LEAK WHEN THE ENGINE IS RUNNING AND THE SYSTEM IS UNDER PRESSURE BUT WILL NOT LEAK WHEN THE ENGINE IS SHUT DOWN.



Pressure caps used to seal the cooling system maintain the closed system until pressure reaches the maximum. Then the cap opens a relief valve (B) that releases pressure to an overflow tube (A).

A newer system used on many new cars is the coolant recovery system (D). The radiator is closed at all times and under pressure. As the pressure builds up in the system (engine running), the radiator cap pressure relief valve opens and coolant escapes to a holding tank (C), instead of being lost out the drain tube. When the temperature drops in the radiator (engine off), the slight vacuum created by the drop in pressure draws the coolant back into the system.

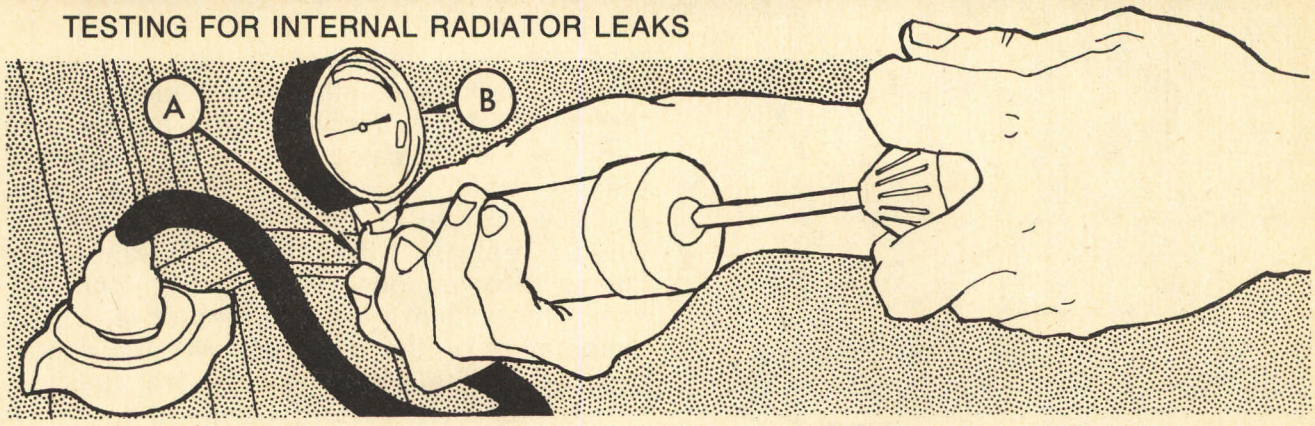
TESTING THE RADIATOR FOR LEAKS



The radiator and hoses can be checked for leaks by using a radiator pressure tester (A). It connects to the radiator filler opening (C) and is pumped up like a tire pump. On the tester is a gauge (B) which indicates whether or not the system is holding pressure. Pay particular attention to the area of the reservoir tanks (the upper and lower portions of the radiator) for evidence of leaks around the hose connections and soldered seams.

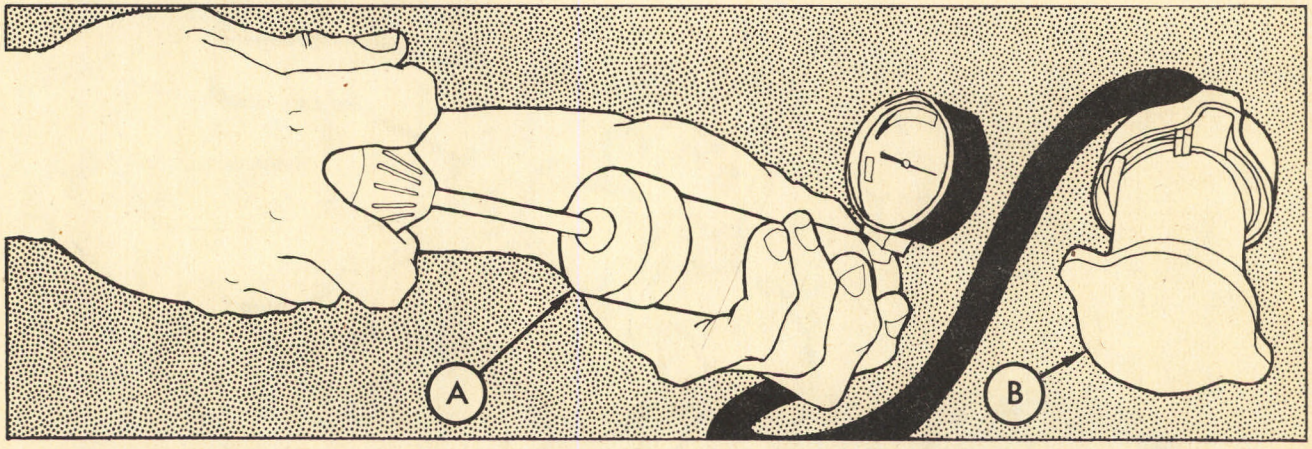
TROUBLESHOOTING COOLING SYSTEMS

TESTING FOR INTERNAL RADIATOR LEAKS



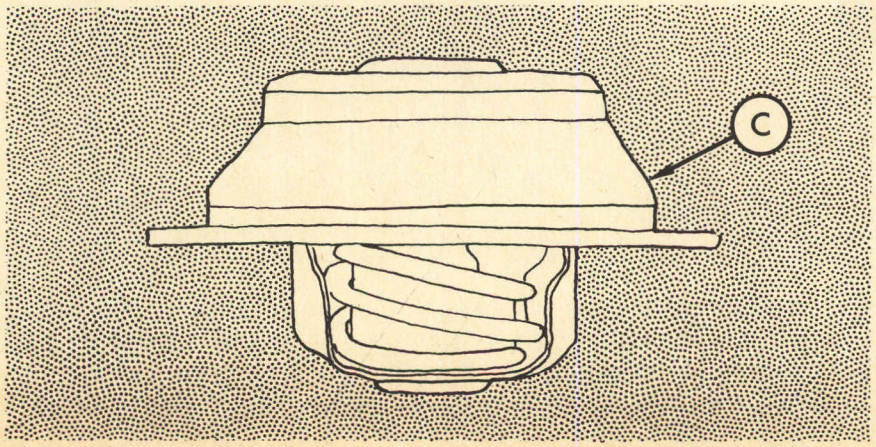
A blown head gasket or a crack in a head or cylinder wall can allow combustion gases to enter the cooling system and let coolant leak away into the cylinders. If the hot combustion gases enter the coolant, it may cause the coolant to heat up faster than normal or even boil. Using the pressure tester (A), pressurize the system to about 7 psi (B) and run the engine. Run the engine at high rpm and watch the gauge for signs of a pressure fluctuation. Fluctuation indicates a combustion leak. On V-8 engines, you can track the problem to one bank or the other by disconnecting all the wires from the spark plugs on one bank. ("Bank" refers to one cylinder head on a V-8 engine. There are four cylinders in each bank or side of the engine.) Run the engine on the other bank. (It will just barely run, but well enough for the test.) If the gauge still fluctuates, the problem is in the running bank. If the gauge does not fluctuate, the problem is in the disconnected bank of cylinders.

TESTING THE PRESSURE CAP

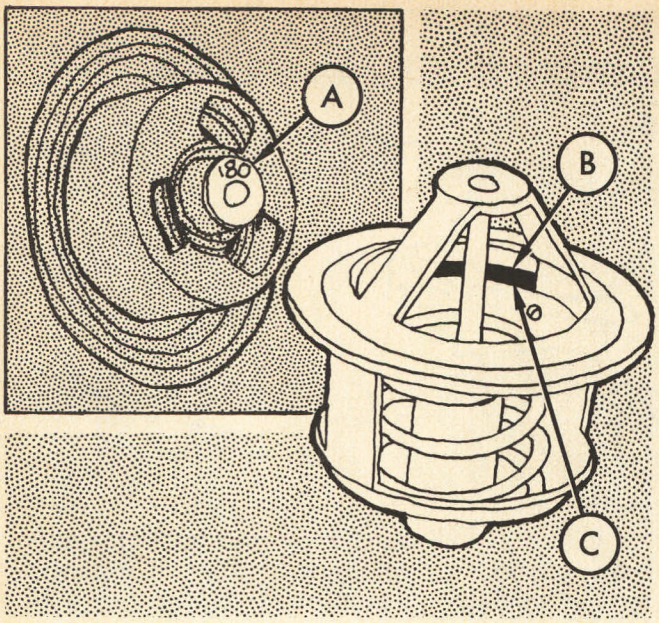


The same tester (A) used to check the radiator for leaks can be used (with a suitable adapter) to check the pressure cap (B).

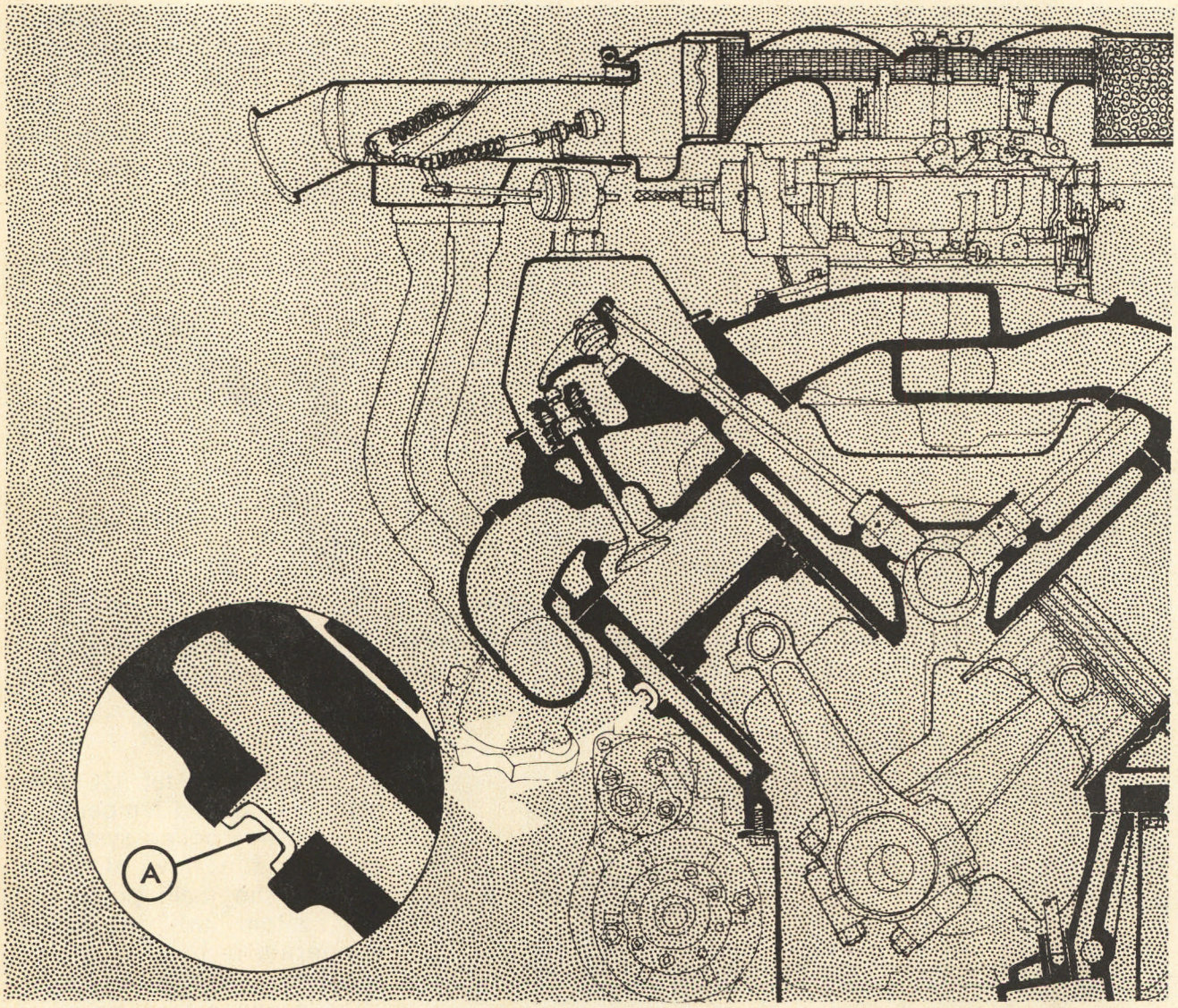
TESTING THE THERMOSTAT



The thermostat (C) maintains the desired temperature level in the cooling system. It restricts the flow of water through the main portion of the system until the water temperature in the engine reaches the desired level. Then it opens to allow all of the coolant to circulate through the radiator. Different engines require different thermostats, each with a specific temperature range.



To test the thermostat, remove it from the engine (see the shop manual for removal instructions). Suspend the thermostat in a container of hot water. Use a thermometer to read the water temperature. See your shop manual for the operating temperature of the thermostat. When the water reaches this temperature, as indicated on the thermometer, the thermostat should open. To check, place a .003-inch feeler gauge between the valve (C) and seat (B) of the thermostat. When the gauge becomes loose, the water temperature should be within a few degrees of the rated temperature on the thermostat (A). If the temperature of the water rises several degrees more, the valve should open all the way (about ¼-inch). When allowed to cool, the thermostat should close. If it does not work easily, replace it.



Another part of the cooling system that should be checked for signs of external leakage is the freeze plugs (A). These are small metal plugs fitted into the sides of the engine block to fill holes left by the manufacturer's casting operation. In time, these may corrode or rust and may leak. Check the shop manual for the location of these plugs and inspect them carefully.

TROUBLESHOOTING COOLING SYSTEMS

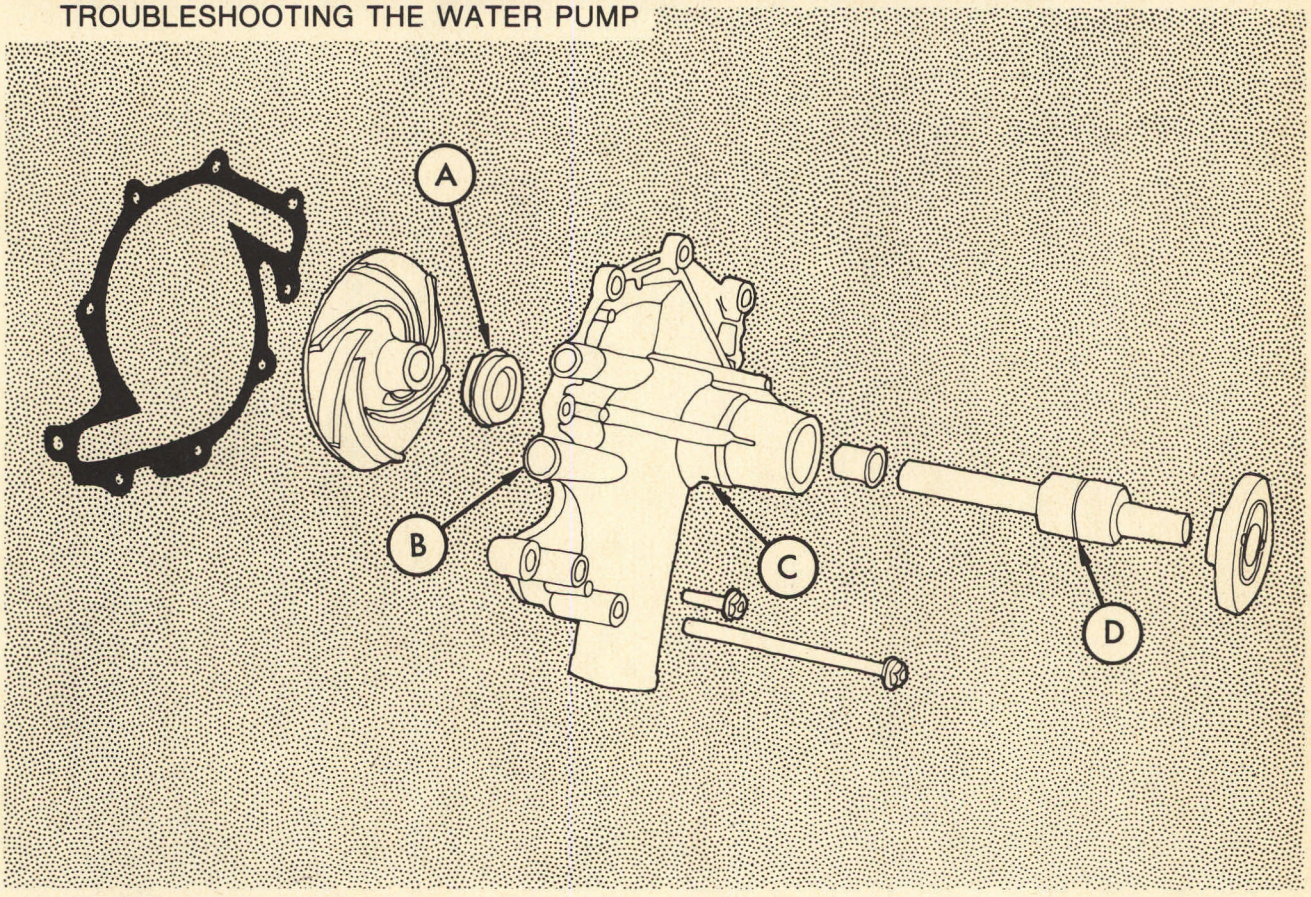
COOLING SYSTEM—COLD WEATHER OPERATION

During winter months, when temperatures fall below freezing, the cooling system should be protected from freezing by the addition of an antifreeze compound. Most of the coolants sold in automotive stores and dealerships have some antifreeze protection, but in severe weather you may need to increase the protection afforded by your coolant by adding more antifreeze. See the shop manual or owner's manual for specific information about your car's requirements.

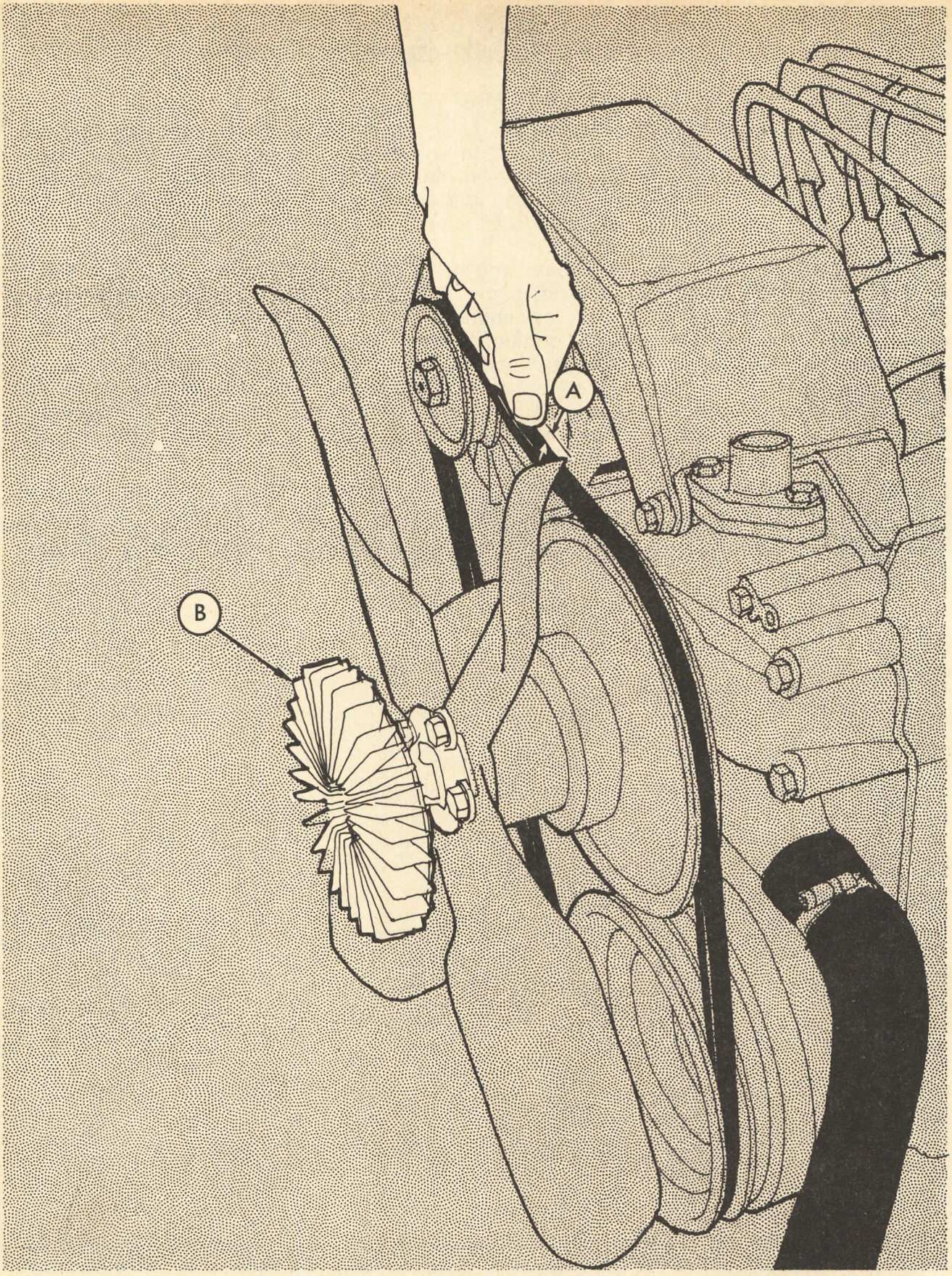
During extended sub-zero cold, hoses and drive belts may become brittle. Both should be inspected at reasonable intervals for damage. Under certain conditions, the temperature of the coolant in the radiator may drop low enough to freeze (this is especially true if plain water or antifreeze with a high water content is being used). If your car overheats in very cold weather without any external signs of cooling system problems, this may be the reason. The answer may be to increase the concentration of antifreeze. A temporary aid to use until you can obtain additional antifreeze is to block off a part of the radiator with cardboard to restrict the flow of air through the cooling fins. This will raise the temperature of the coolant already in the radiator enough to prevent freezing.

CAUTION: BE CAREFUL WITH THIS TEMPORARY METHOD. DO NOT BLOCK SO MUCH OF THE RADIATOR THAT THE ENGINE OVERHEATS.

TROUBLESHOOTING THE WATER PUMP



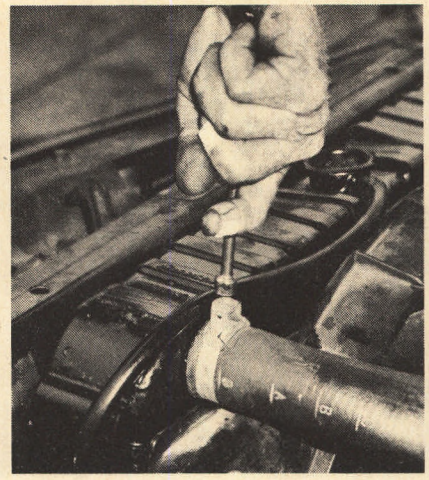
The water pump (B) on most engines is highly reliable. There isn't much that can go wrong with it except wear of the bearings (D) or loss of a seal (A), allowing the pump to leak. If you are experiencing coolant loss and cannot find any leaks in the radiator or hoses, examine the bottom of the water pump. There is a small drain hole (C) on the underside of most pumps. If the pump has a bad seal, traces of water can be seen on the front of the engine under the pump. Water pumps are not repairable without special tools. If the pump malfunctions, replace it. Also check the fan belt. A loose belt will cause the pump and fan to run more slowly than is needed for good cooling.



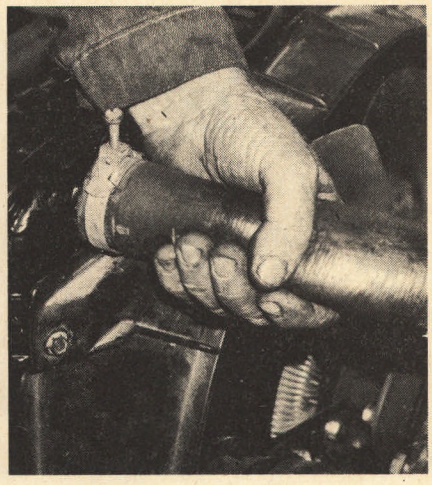
Adjust the fan belt tension according to the owner's manual or shop manual for your car. A simple rule of thumb is to keep the belt tight enough that you can move it only about ½-inch (A). Both the belt and the pump itself will often give an indication of trouble by making squealing noises. The fan itself usually causes no problem, but many fans are attached to a drive (B) that disconnects the fan when the engine is running at high rpm. If the drive fails, it can cause overheating by preventing the fan from turning at low engine rpm.

HOW-TO: Removing Radiator

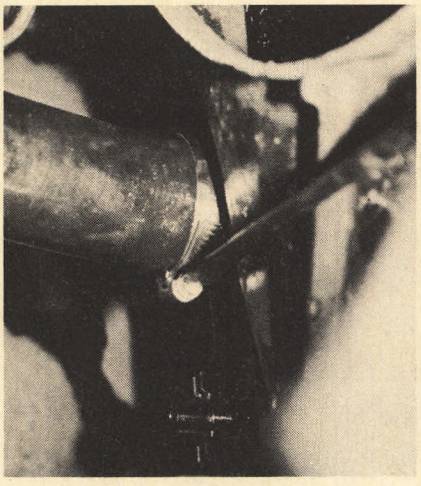
1. Removing a radiator is one of the easiest things you can do in your own backyard. Place a container beneath the drain cock to catch the coolant.



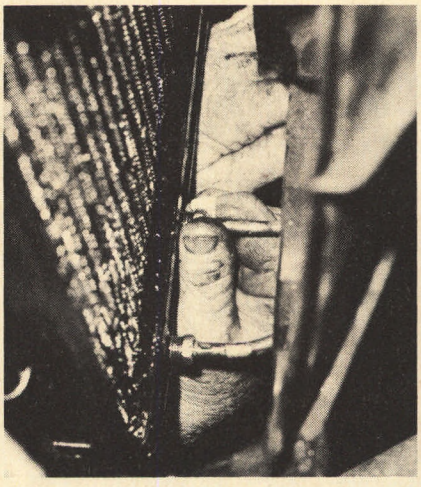
2. Remove the radiator cap so air can displace coolant, then open drain and let fluid out. When radiator is empty, loosen upper connecting hose clamp.



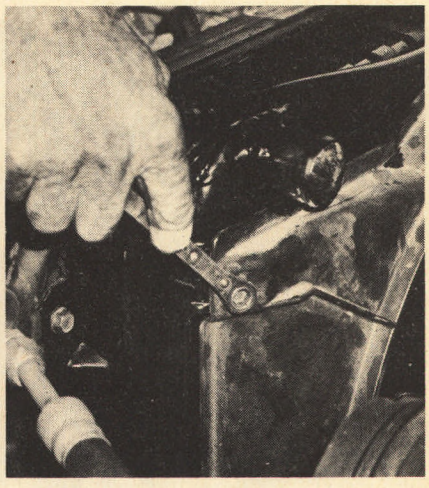
3. Grasp the hose and twist it as you pull it off. It may require twisting back and forth several times to break the hose loose from radiator inlet.



4. The lower hose is usually hard to reach from above. Use an extra long screwdriver to avoid scraped knuckles, or you may have to reach it from below.

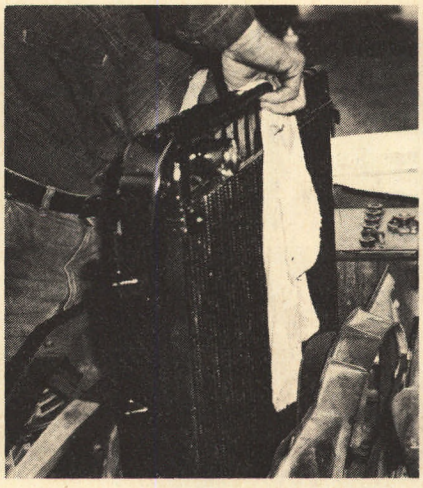


5. The automatic transmission cooling lines are best disconnected from below using an open-end wrench. Jacking car up may make access to lines easier.

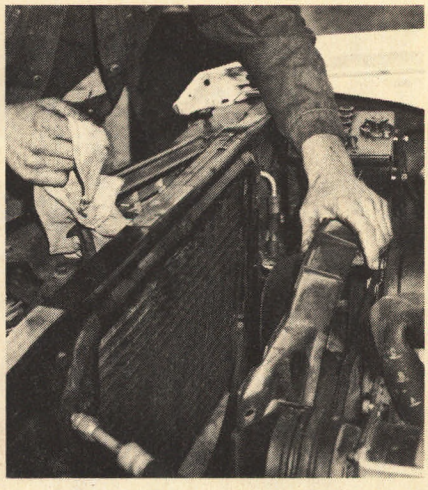


6. Now, remove the capscrews that hold the radiator shield in place. A box wrench is best to avoid rounding off the heads of the capscrews.

7. A socket wrench will come in handy when you take out the bolts holding the radiator. There are usually four, one in each corner of the frame.

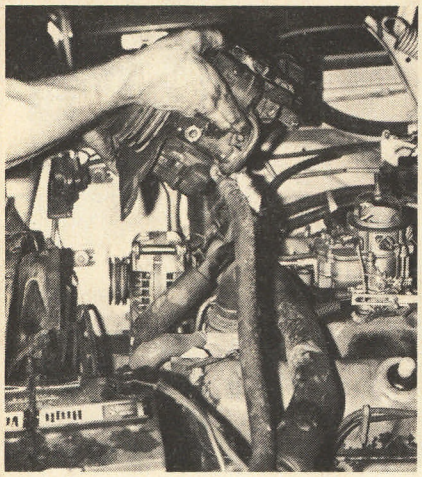


8. Lift the radiator up and out, angling it if necessary. Be careful to not scrape fin surface. On some cars removal of the fan may be necessary.

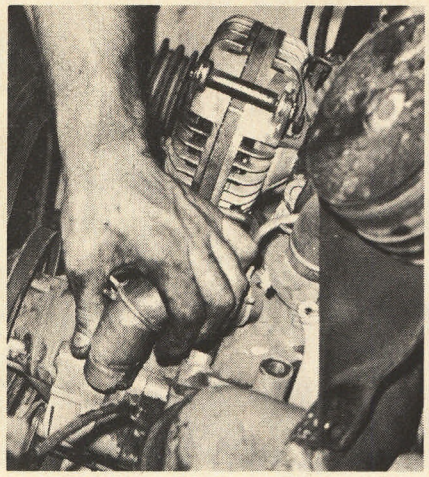


9. Either hang the shield back behind the fan pulley or remove it. Now you are ready for a trip to the radiator shop for repair or cleaning.

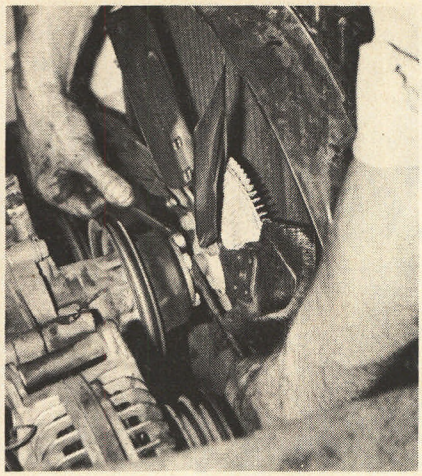
HOW-TO: Removing Water Pump



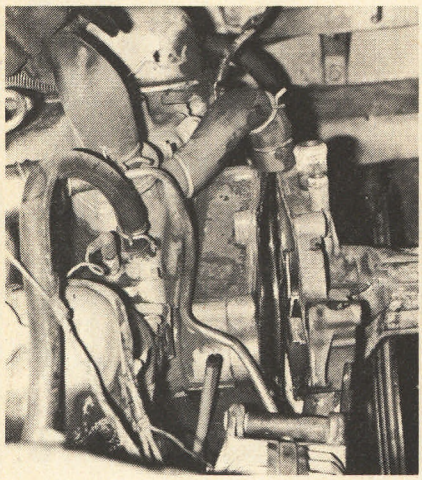
1. Before pulling the water pump, it will be necessary to remove everything blocking access. Here we've unbolted the air-conditioning pump.



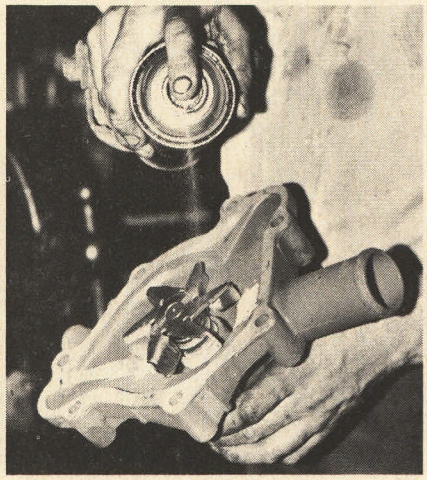
2. Once we've got clear access to the water pump, all connecting hoses are detached. Drain radiator to prevent a mess and to save coolant fluid.



3. The fan usually has to come off to provide clearance for pump removal. Be careful not to gouge the radiator fins. Finally, remove the drive belt.

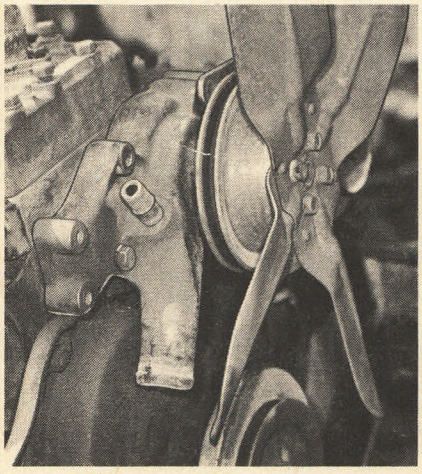


4. After all the pump retaining bolts have been removed, a sharp blow with a mallet will break the pump loose. Some may require only wiggling.



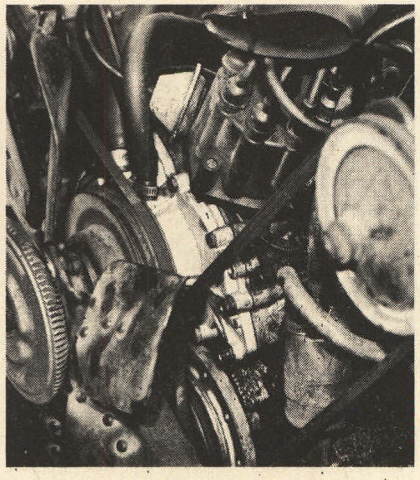
5. Before replacing new water pump, use a dab or spray of adhesive to set the gasket in place. It's no fun to get pump on, then find a gasket leak.

6. Other problems may arise when you dig into the water pump area. Extreme corrosion as shown here means that the radiator hose has to be replaced.

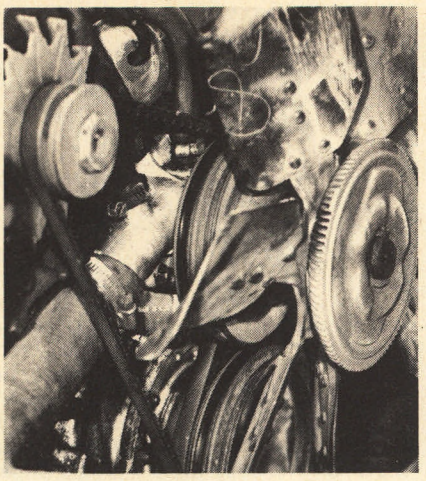


7. In days past, water pumps were relatively simple affairs. It took only the removal of six bolts to remove the pump from a Kaiser-Frazer engine.

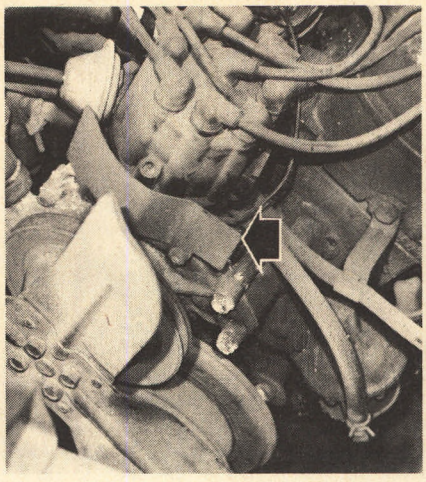
8. The pumps used on the 6-cylinder Ramblers were a snap to remove, too. Taking off one V-belt and five bolts put the whole thing right in your hand.



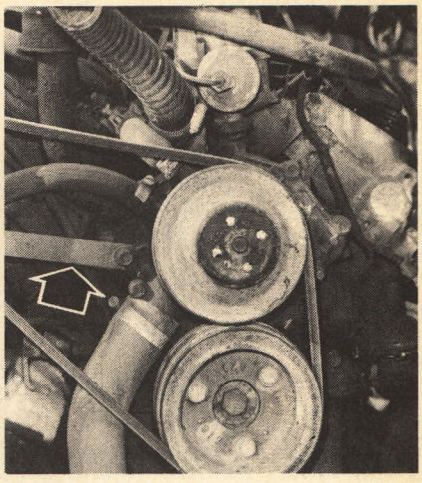
9. But now, the average V-8 engine pump is more complex. You'll have to pull the fan, a pair of belts and three hoses to get this one off a Buick.



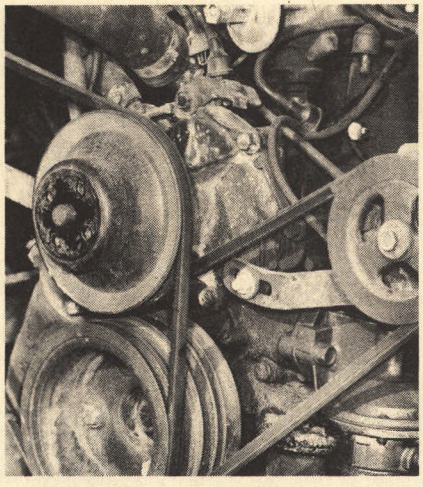
10. Other side of the same Buick shows alternator and three hoses which must be removed for pump access. Be sure new hoses are available, just in case.



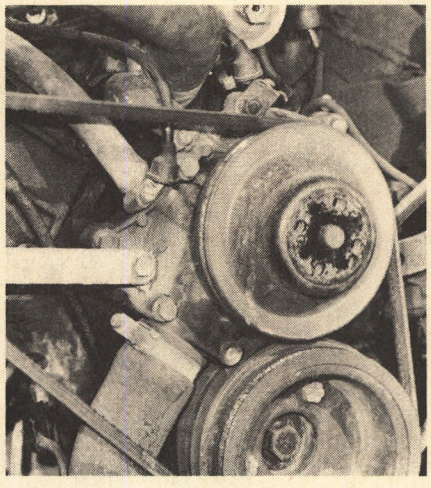
11.The F-85 uses a shield to protect the distributor in case of water pump failure. It will come off when you remove the water pump unit.



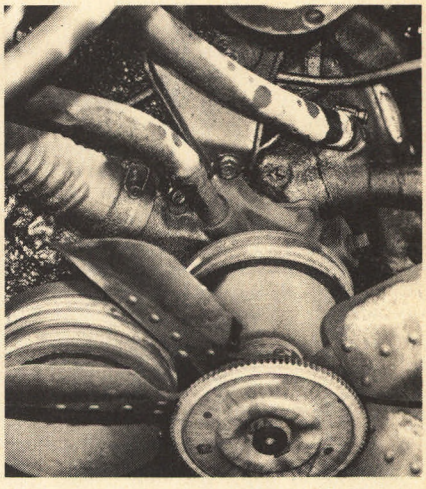
12. Similar to the Galaxie, this Fairlane pump has the alternator bracket attached. It has to be removed before the water pump can be taken off.



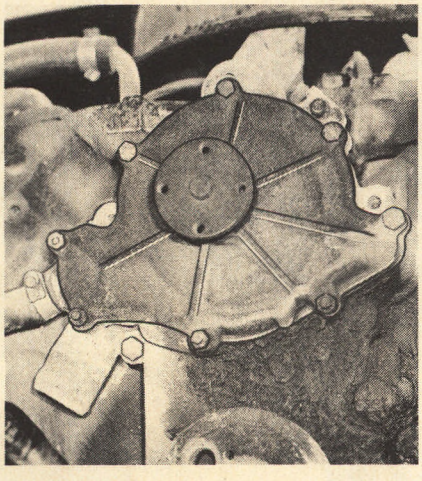
13. On the Galaxie 500, the pump has a bracket on either side. Both of them have to come off, making the job just that much more difficult.



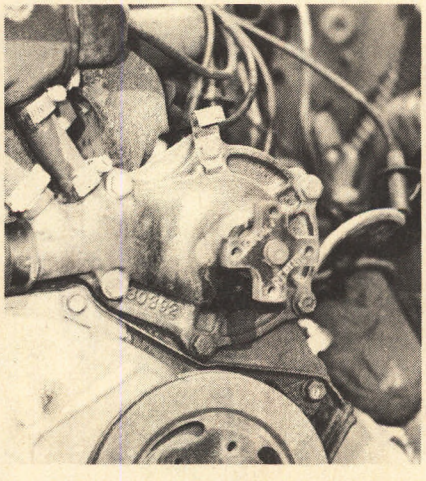
14. Other side of the Galaxie looks clean, but that's because the fan and the radiator have been removed. This allows more wrench-swinging space.



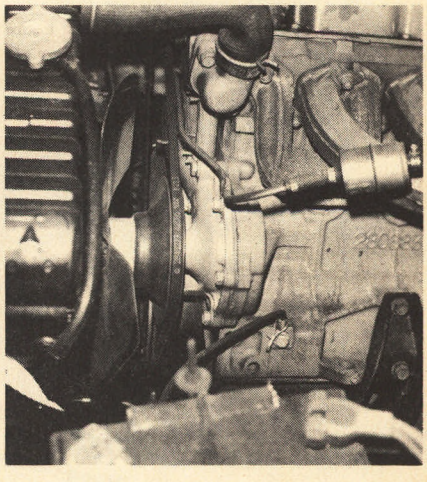
15. The Bel Air pump has a bracket and two hoses that have to come off. This will be a greasy, grimy job on older cars with a lot of mileage piled up.



16. Once everything is stripped off, as on this Catalina, there should be no difficulty in getting at the water pump itself. Again, it's a dirty job.



17. Although it may be funny looking when you get right down to it, your Dart or GT won't run very long if the pump fails. This one's easy to pull.



18. Check the thickness and the number of gaskets on the pump. Some pumps may require two gaskets so the impeller doesn't hit block inside pump cavity.

Exhaust System

Many people consider a car's exhaust system in the same light as a sewer pipe. It's necessary, but it isn't something that is very interesting or pleasant to work on. But an exhaust system is not just a bunch of tubes to get rid of waste gases. It can result in your engine running good or bad because of a little gadget in the exhaust called the exhaust manifold heat valve. Many engines have this valve, whether they are 4's, 6's or V-8's. Its purpose is to block the direct exit of the exhaust gases from the manifold and force them along a path that leads through the intake manifold under the carburetor. The exhaust gases heat up the passages in the intake manifold and thereby aid in more complete vaporization of the gasoline. Good vaporization is necessary to prevent a stumble when you step on the throttle. Believe us, the exhaust heat valve really does its job. We have seen engines that could be warmed up until they were just about as hot as you could get them and they would still stumble when you step on the throttle just because the heat valve was frozen in an open position. Free up the valve so that it worked properly and the car would run like it was just off the showroom floor. Cars that do not have the heat valve in their exhaust system usually circulate coolant from the engine block through a passageway in the intake manifold just under the carburetor. Some late model cars have been able to do away with the heat valve because they have a hot air inlet on the air cleaner for the carburetor.

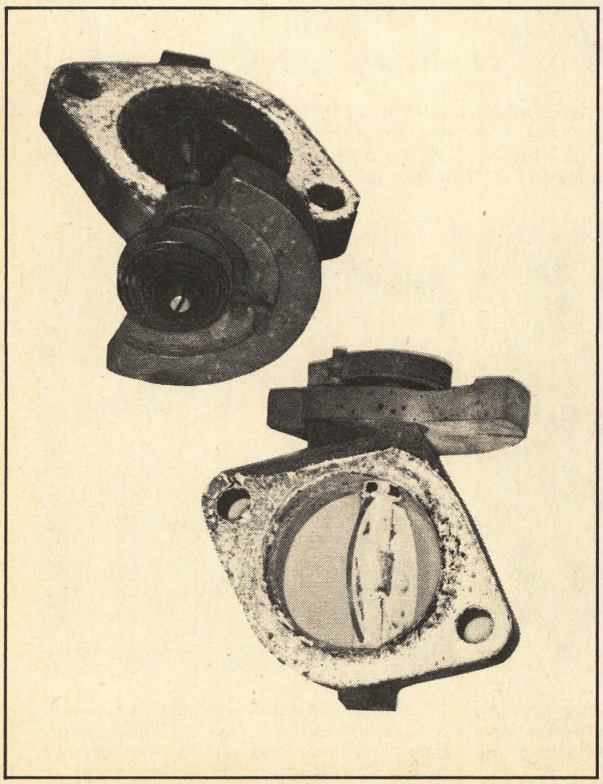
Exhaust heat valves are usually held in the closed position by both a weight and a spring. The spring relaxes as the exhaust heats up because not as much heat is needed under the carburetor when the engine is warm. The weight is offset so that it has a tendency to hold the valve in the closed position, but the valve itself is also offset on a shaft so that any excess rush of exhaust gases will have a tendency to open it. A combination of these factors results in an exhaust heat valve that forces the right amount of exhaust gas through the heating passages in the intake manifold so that the engine operates without any stumble and has sufficient vaporization of the gas to get good gas mileage.

HEAT VALVE PROBLEMS

The valve, regardless of type, can cause a lot of trouble under certain conditions. If the car is driven only short distances at a time and never completely warmed up, the conditions are present in the heavy condensation of moisture while the engine is cold plus the extra carbon caused by the engine running "rich" on a partial choke setting. The moisture and carbon don't need much time to "freeze" the shaft on the butterfly valve in the closed position. Once rust and carbon have a good grip on these exhaust thermostat valves, all the high-speed driving in the world won't free them. All exhaust gases from the cylinders on the side with the "frozen" heat valve must therefore pass through the heat riser passages of the intake manifold. Not only does this make four cylinders practically useless but it also insures an over-supply of heat to the base of the carburetor, making "vapor-lock" a cause of distress in many cases.

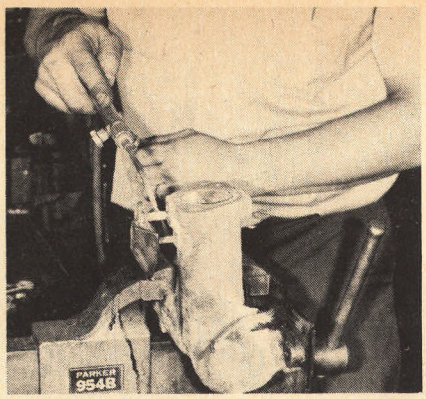
If the car is factory equipped with a dual exhaust system, a butterfly-type heat valve will be located between one of the exhaust manifolds and the exhaust headpipe which leads to the muffler. If this valve should become "frozen" due to the above conditions (excessive oil consumption will also help "freeze" the heat valves), the exhaust must still pass through the intake manifold risers and into the opposite exhaust manifold.

If your car uses the obsolete, internal "duck bill" heat valve, the crosspipe between manifolds has to be taken off to make sure that the valve is not choked shut. The other type with an external spring and weight can be checked while



1. Exhaust Manifold Heat Valve

2. Replacing Muffler



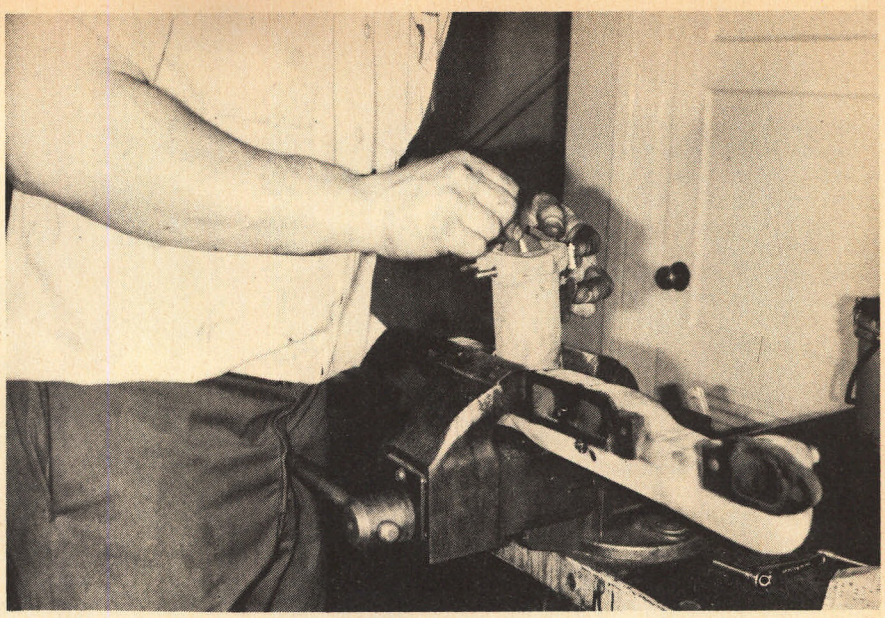
3. Cutting Valve Shaft

cool to make sure that the shaft through the collar holding the butterfly valve will move freely. If frozen, it can sometimes be loosened by moving back and forth by hand until the rust is broken loose, then lubricating with special manifold heat valve lubricant. If this doesn't do the job, then a new valve should be installed in its place.

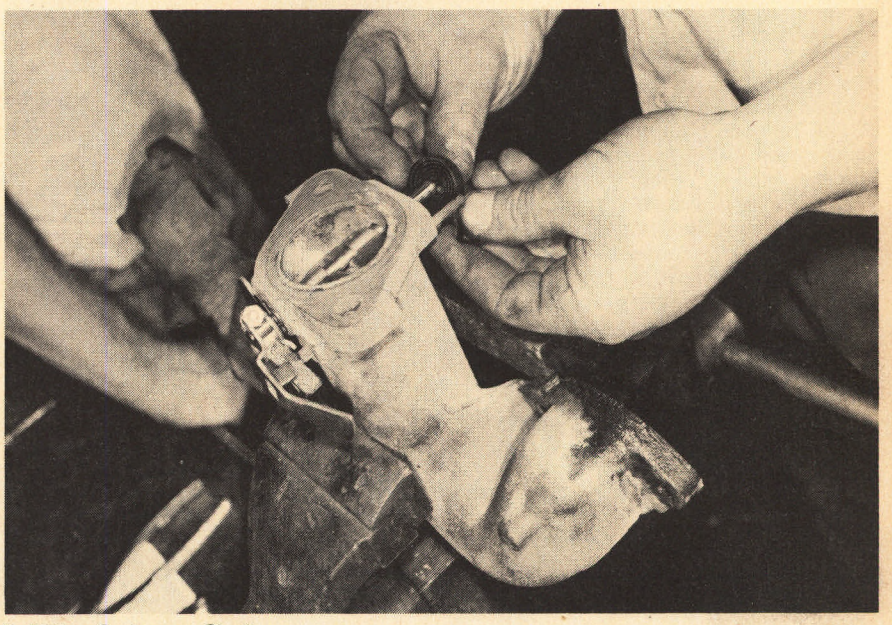
TYPES OF MUFFLERS

Most stock mufflers are designed to lower noise to a minimum and contain a series of baffles and noise-deadening chambers through which the gases must pass. These stock mufflers have a restrictive effect on the exhaust gases but this restriction is not too great at low engine speeds. As the engine speed increases and more gases are crammed through the muffler, the back pressure in the system increases and engine efficiency is lowered. This well known fact has been the big reason for the popularity of dual exhaust systems for many years among the hot rodders, and it is also the reason that most of the higher powered stock cars use dual exhaust systems.

By using a dual system, the automotive manufacturer has cut in half the volume of gases to be muffled by a stock muffler but he has also increased noise. The



4. Inserting Weight & Shaft Assembly



5. Fitting Spring on Shaft

6. Retaining Spring

1. The exhaust manifold heat valve, at the end of the exhaust manifold, tends to have deposits build up on the baffle shaft, causing the valve to stick and the engine to either vapor lock or stumble on takeoff.

2. Chances of fixing an exhausted exhaust system are next to nil. Most become so corroded by salt or sulphur that the repair job becomes strictly "remove and replace."

3. When carbon and rust "freeze" the exhaust heat valve, best bet is to replace it. Here the valve shaft is cut with a torch; you can use a hacksaw to do the same thing.

4. New shaft and weight assembly is inserted through butterfly heat valve in exhaust headpipe.

5. Spring is fitted on shaft with end of spring against headpipe stud.

6. Retaining spring fits over end of heat valve shaft and headpipe stud. Spring and weight hold valve in closed position.

fewer cylinders per muffler, the more the noise. In other words, a stock muffler for each 4-cylinder bank of a V-8 engine will produce more noise than if one of the same mufflers is used for all eight cylinders. To keep this noise down, the number of baffles and chambers has been increased, with the end effect that the newly found horsepower due to the dual system is lost, especially at high engine speeds, due to the increased restriction and back pressure in the muffler.

Straight-through type mufflers are, as the name implies, straight-through with no restrictive baffles or chambers. The center pipe can either be slotted, drilled, louvered, saw cut or even a large twisted spring type. The area between the center pipes and the muffler shell is then packed with steel shavings or fiberglass to absorb the exhaust noise that passes through the openings in the center pipe. While very efficient in exhausting the burned gases, the straight-through type does not always lower the exhaust noise to the desirable minimum. If the noise level is too high after the installation of the straight-through mufflers, a resonator muffler can be added.

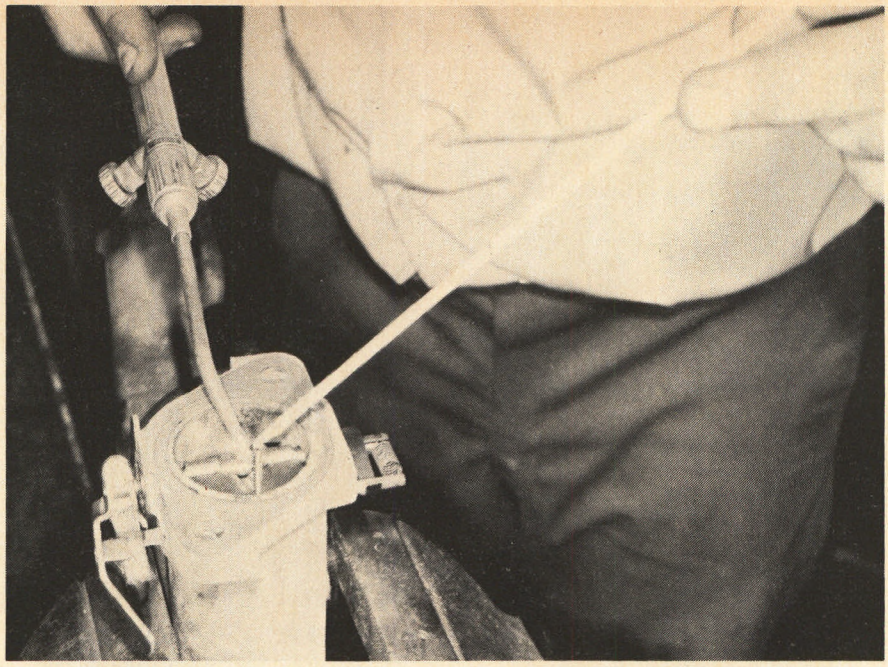
The resonator muffler is actually in most cases just a short-length, straight-through muffler, either glass or steel packed, that is installed in the exhaust system to provide extra sound muffling to the exhaust. These resonators can sometimes be placed in the tailpipe behind the regular muffler to provide maximum quietness. Exhaust gases cool off as they near the rear of the car, which causes the volume of gas to be lessened. When resonators are installed near the end of the exhaust system, the cooler gases are more easily muffled due to the decrease in their volume.

While the heat valve is, as mentioned, one of the main causes of grief in the exhaust system, the prime enemy of the entire system is the moisture content of the exhaust gases. This moisture is by no means pure water but contains all sorts of corrosives, the main one being sulfuric acid from the sulfur content of the gasoline and oil. In a car that is being operated mainly for short trips, such as going to the store or school, this acid-laden moisture can collect in all sorts of places where it eats away at the thin-metal exhaust pipes and muffler shell until these pieces look as if moths with tungsten carbide teeth have been at them. Particular trouble spots are dips in the tailpipes ahead of the rear axle, the section just behind the axle, the rear end of the headpipe and the bottom of the muffler shell.

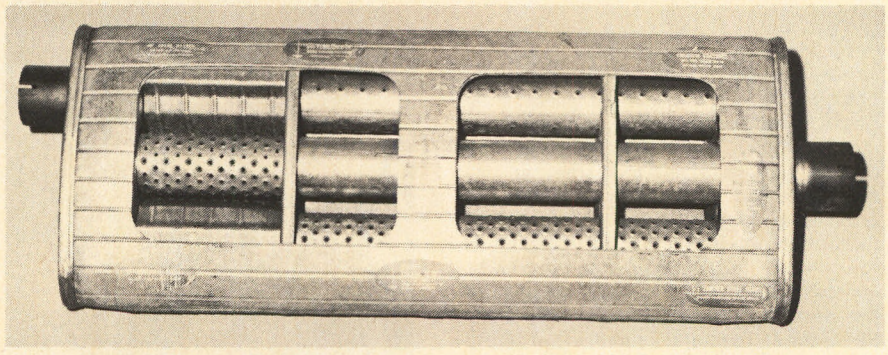
Other areas prone to attack are, unfortunately, the joints where the various pipes are attached to each other, which can make things a bit tough to pull apart. However, there is one good thing about it: This is the one area of repair where you can vent your feelings with a hammer and chisel and epithets.

MUFFLER REPLACEMENT

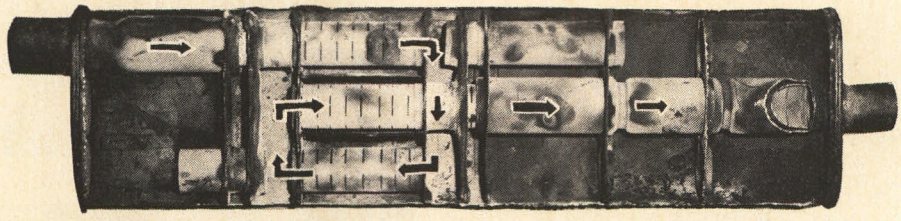
There is no such thing as "repairing" or "fixing" a deteriorated exhaust system; all you can do is replace it. Conse-



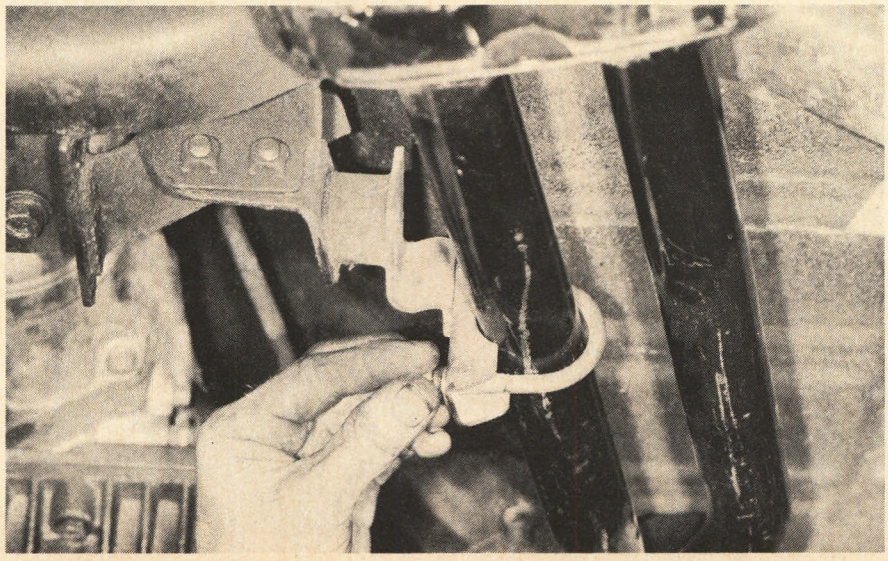
1. Welding Valve



2. Cutaway of a Typical Muffler



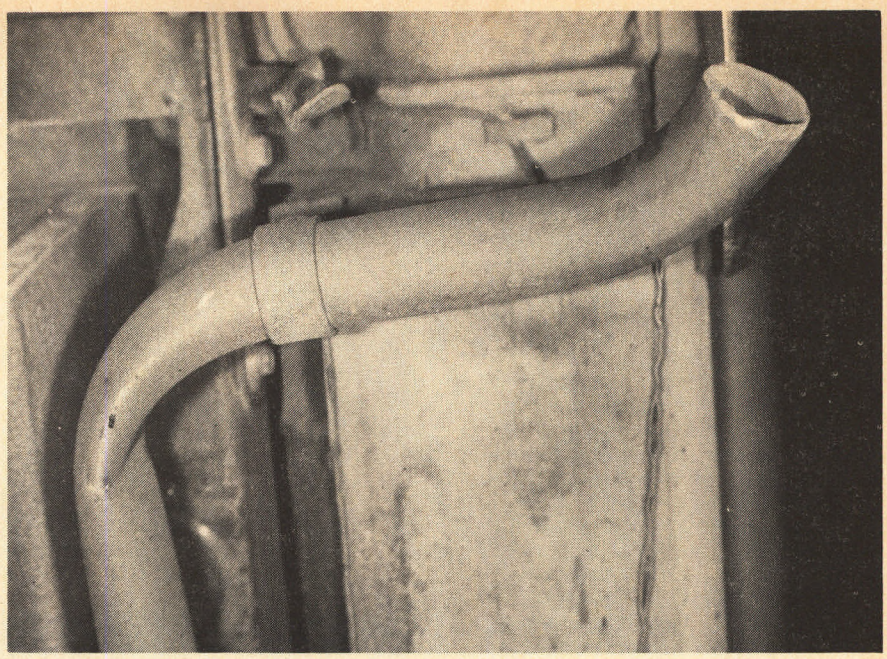
3. Exhaust Flow Through a Muffler



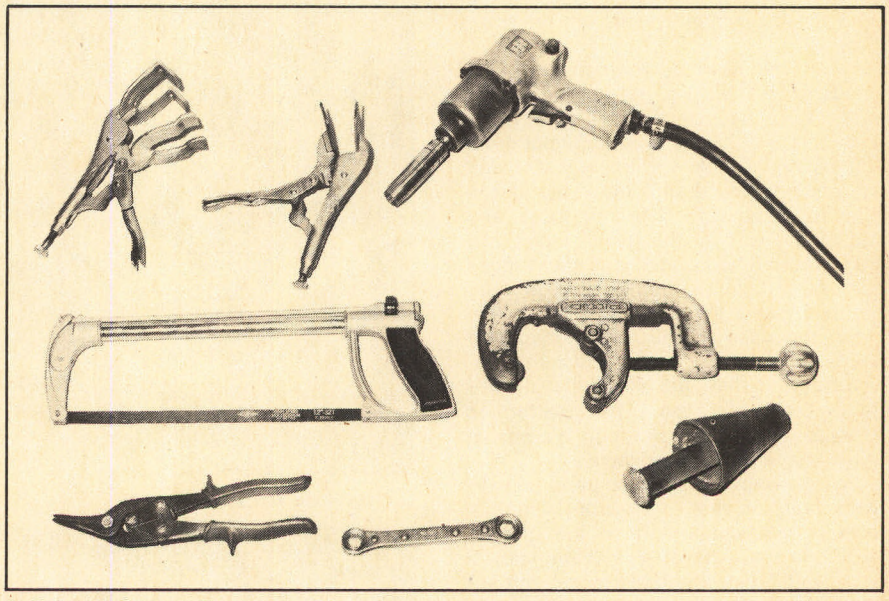
4. Bracket and Clamp Support

quently, as long as you confine your attentions to the pipework and muffler, you can bang away to your heart's content. If you have access to a torch and know how to use it, you can flame-cut the corroded joints—which is how the professionals do it—but it isn't absolutely necessary. All that is needed is a hammer, a round-nose or diamond point chisel, a hacksaw and a set of open- or box-end wrenches. Exhaust system work is neither the cleanest nor the messiest form of auto repair work but it is pretty much the simplest and, for the home or amateur mechanic, generally the starting point after plug-changing and simple tune-ups to bolster his confidence.

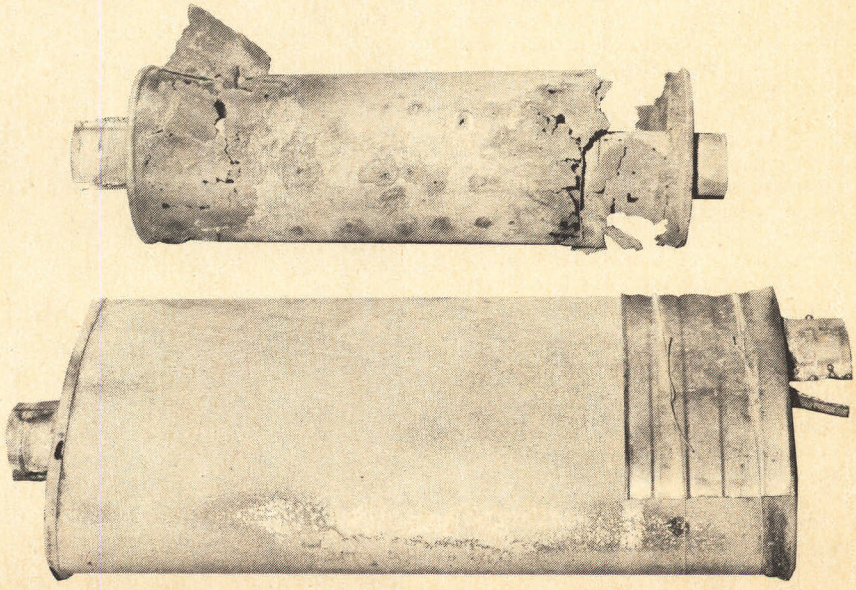
The first step in any exhaust work, unless you're a midget or claim kinship to the worm family, is to get the car up off the ground. If you can gain access to the use of a hoist or greasepit, so much the better but it isn't necessary. What is necessary is a safe method of supporting the car. By "safe" we don't mean a couple of bumper jacks or packing crates. If you can possibly afford it, purchase four adjustable jack stands from any parts house, Sears, Montgomery Ward or one of the automotive chain outfits such as



5. Bent Tailpipe



6. Exhaust System Tools



7. Rusted Out Mufflers

1. As butterfly valve revolves freely on shaft, the two are welded with the valve in the closed position. Screw seen here was wedged in against valve to hold it correctly for welding and is removed once job is finished.

2. The quiet stock mufflers, with their many pipes, chambers and baffles, tend to corrode faster than the straight-throughs because they trap and retain exhaust condensation, which is loaded with sulphuric acid.

3. The restrictive nature of common mufflers will seriously affect the high-speed operation of an internal combustion engine. More efficient dual exhaust systems, featuring either smaller mufflers or straight-throughs, can be purchased and installed for less than $100.

4. U-clamps must be securely fastened with enough clearance for the bracket to stop any rattle problem.

5. This station wagon was backed too closely against a parking lot wall, causing a severe bend in the tailpipe that restricts exhaust passage. As you may not realize this happens, it's a good idea to periodically check the pipe.

6. These are the basic tools the pros use to make the job an easier one. Shown top row, from left: vise grip-type welding clamps, air-operated impact wrench; middle row, from left: hacksaw, pipe cutter; bottom row, from left: sheetmetal shears, ratchet-type box-end wrench, and a tube or pipe expander.

7. Even though the high sulphuric acid content of the exhaust gas condensation causes rapid deterioration of the muffler, some tightwads try to extend the life of their noise suppressors by covering the rust holes with pieces of sheetmetal.

Exhaust System

Pep Boys or Western Auto. If you can't see your way to such a purchase, borrow the stands or at the very least go down to the lumber yard and get enough solid 4-by-8 blocks to hold the car securely suspended once it has been jacked up. Never trust a jack to hold the car while working other than changing a tire. Bumper jacks can slip and even hydraulic jacks can be inadvertently bumped and lose pressure in an instant.

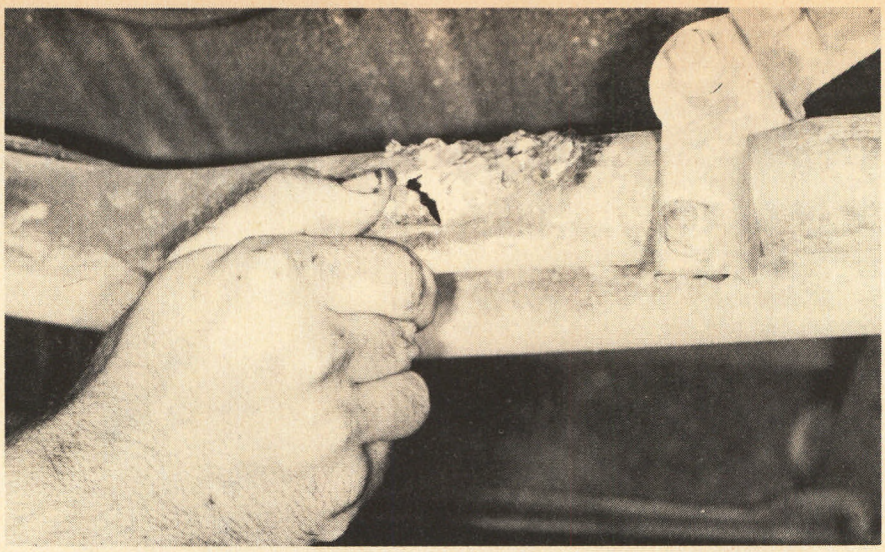
Once you have the car up and blocked, get under and look at the exhaust system. If the tailpipe shows signs of rot or corrosion, the muffler is almost sure to be the same inside although it doesn't show on the outside. In virtually every case you'll find that if the muffler needs replacing, the tailpipe will also need replacing, and vice versa. Not so, necessarily, in the case of the headpipe—the pipe that leads from the manifold to the muffler. It's made of sterner stuff than the rest of the system and, being subject to hotter gases, tends to stay dry. But if it is corroded, it's a sure bet the whole system will need replacing.

When you have determined just what needs to be replaced, get out the appropriate wrenches, generally 1/2, 9/16 or 5/8-inch, and loosen all the clamps from the piping. Knock the ones that aren't attached to the frame back along the pipe to make sure they are loose and out of the way of the joint. Unbolt any that are attached and knock them loose too. At this time check the attaching straps to see if they are brittle or broken, or in the case of the rubber-insulated ones, if the rubber block is loose or deteriorated. If they are faulty, they'll have to be replaced, too. The unattached clamps—and those attached clamps in good shape—will be reusable.

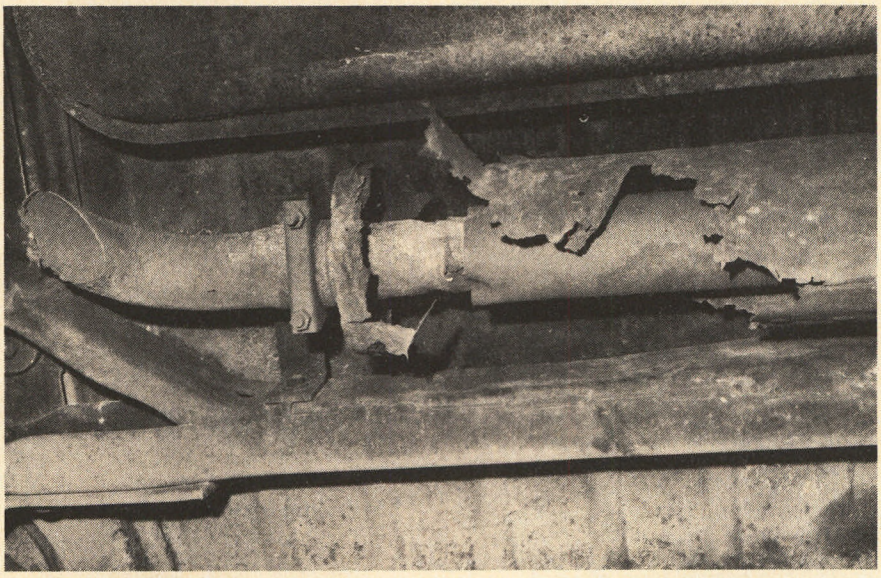
When removing exhaust parts, always work from the rear to the front. The tailpipe is removed first, then the muffler, and then the exhaust pipe (headpipe). If you can't break the joints loose with liquid wrench, and you don't have a torch to do it like a muffler man does, then you will have to cut a slot in the pipe or muffler with a chisel. Of course, that ruins the pipe or muffler, but, hopefully, that will be the part you want to replace anyway. Don't expect to do muffler work with a butane torch or blowtorch. Breaking rusty joints loose requires an oxy-acetylene torch.

Tap the headpipe along its length with a hammer. If it rings true, it's probably in good shape; if it doesn't, it's either cracked or corroded through and should be removed and replaced, a simple wrench job. Do the same thing with the crossover pipe in a single system or, if you are changing to duals, remove it entirely to make way for the new left-bank headpipe.

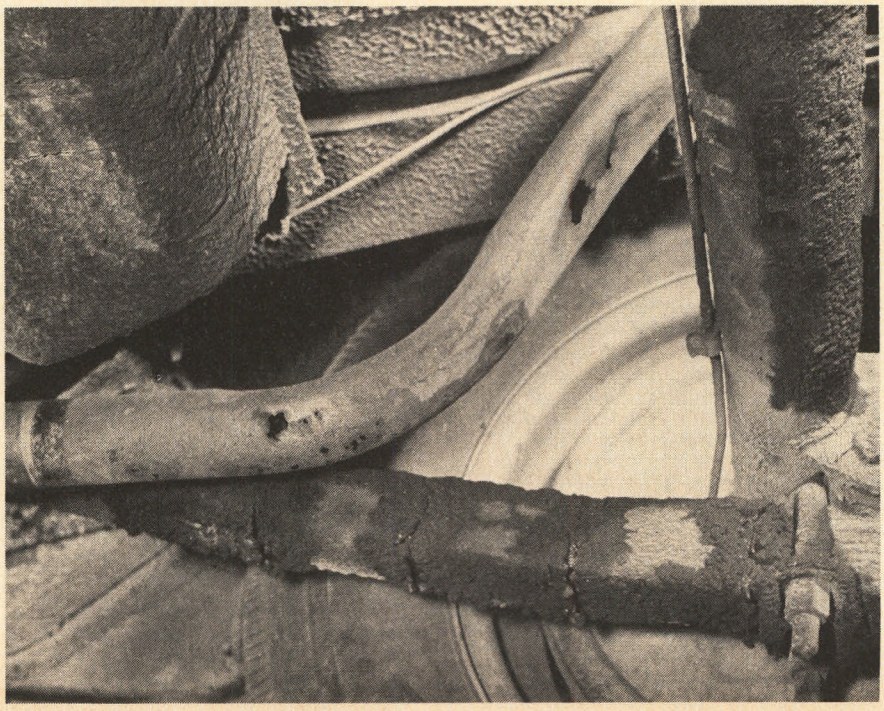
When purchasing the new components, be sure you state not only the make and model but whether the car is equipped with automatic shift or power steering as these items sometimes require different pipe routing from those models not so equipped. With the new equipment in hand, installation is a



1. Damaged Tailpipe



2. Neglected Exhaust System

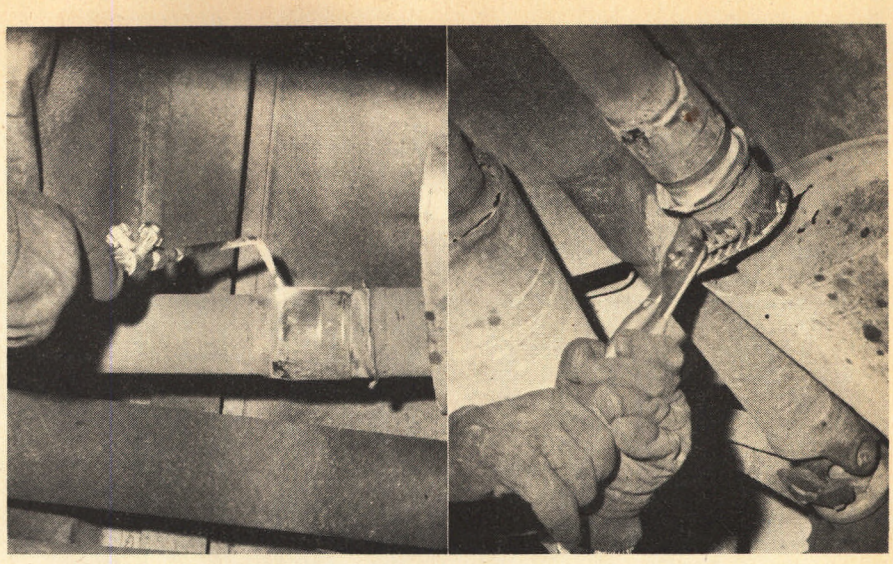


3. Rusted Out Tailpipe

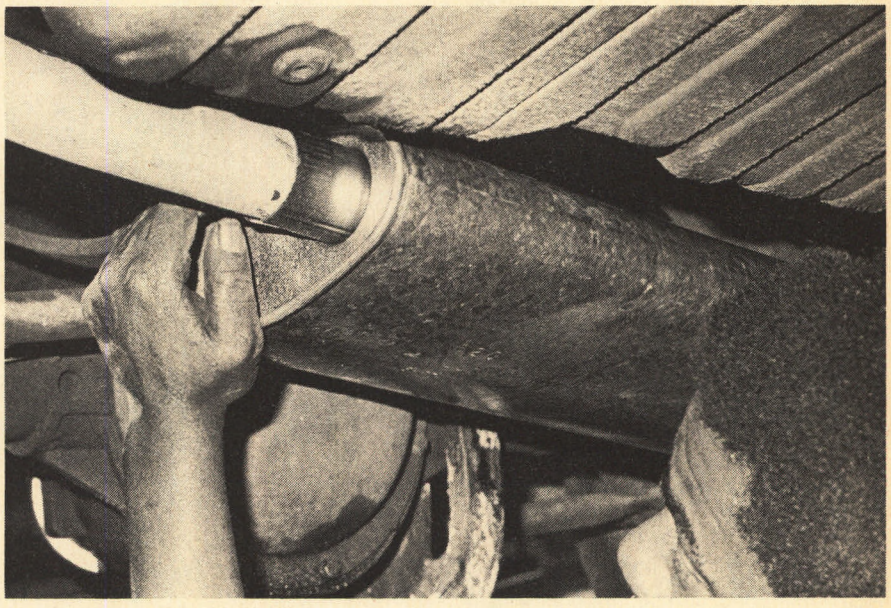
breeze but a certain amount of care should be taken. Headpipe ends should be thoroughly cleaned with a wire brush and coarse sandpaper if you are retaining the original units. If they are also being replaced, use a wire brush or a knife to scrape the manifold outlet flange surfaces, making sure that there are no pieces of the original gasket material left which can cause a leak when the new gasket and pipe are installed. Put all the clamps involved near their proper places along the pipe, leaving them loose enough to move freely back and forth. Lift the muffler and slide it on the headpipe, again leaving all clamps loose. Then slide the tailpipe over the rear axle and join it to the muffler. You may have to use a jack on the car frame to raise the frame and body high enough for clearance to get the tailpipe in position. If so, put stands or blocks under the frame in case the jack should fail. Loosely bolt all the clamps that attach to the frame to their attachment points. Now the system is in place but loose enough to move about within restricted space limits.

The next step is to align all the components so that none of the piping rubs against the frame, fuel lines or brake lines—in other words, so that the whole system is completely isolated from other chassis components except where the various insulated clamps and straps attach to the frame. After a complete recheck, tighten all bolts and clamps so that you have a completely solid system. If you are replacing or installing duals, repeat the procedure on the opposite side of the car.

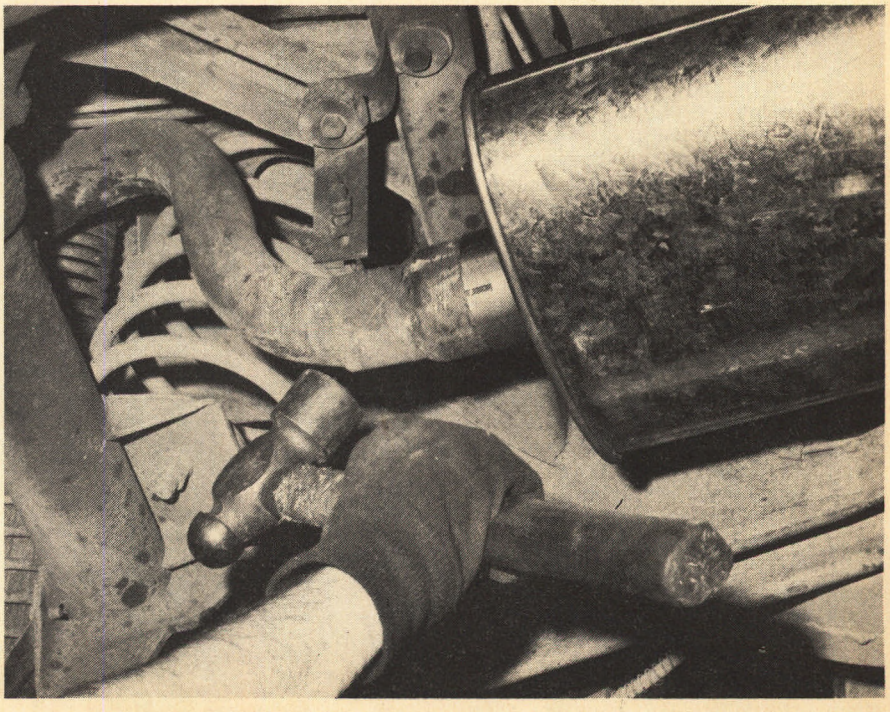
Now you can fire up the engine. Set it on a fast idle and listen carefully for any hissing, intermittent spitting sounds or



4. Heating Muffler; Using Pliers



5. Sliding Muffler on Tailpipe



6. Forcing Tailpipe over Muffler

1. Occasionally, you can extend the life of a manifold or tailpipe by welding the damaged area, but it's only temporary, since the exhaust gases continue to eat the pipe away. Remove and replace—this is certainly the best and safest bet.

2. Most mufflers are galvanized or otherwise protected against rust from road salt and water, but the truth is that they rot out from the inside due to corrosive exhaust gases. A bad exhaust system can be a fatal oversight, especially on eastern cars whose floorpans may be rusted out too.

3. Tailpipes rot where the exhaust gases condense. Rule of thumb here is the closer you get to the engine, the less the chance of heavy corrosion. Heat eliminates condensation.

4. In the not-so-tight-situations, most pros heat the two pipes to a cherry red condition, then work the pipes free with a set of interlocking joint gripping pliers.

5. The new muffler or resonator is then slid over the tailpipe, using a twisting motion. Even though they're made out of galvanized stock, resonators are usually the first portion of the exhaust system to go because of condensation buildup.

6. The flat end of the ball peen hammer can be used to force the old tailpipe onto the new muffler end.

droning of metal-to-metal contact that might be telegraphed through the frame. If you have done the preparation and installation carefully, there should not be any such noises. If there are, leave the engine running and locate the source. It is much easier to correct any faults at this point than later when carbon and beginning rust will make moving the pipes either extremely difficult or downright impossible.

Once completed, that should about do the job. However, for the first few days of driving, listen for any odd noises and, if they occur, find and cure them as soon as possible.

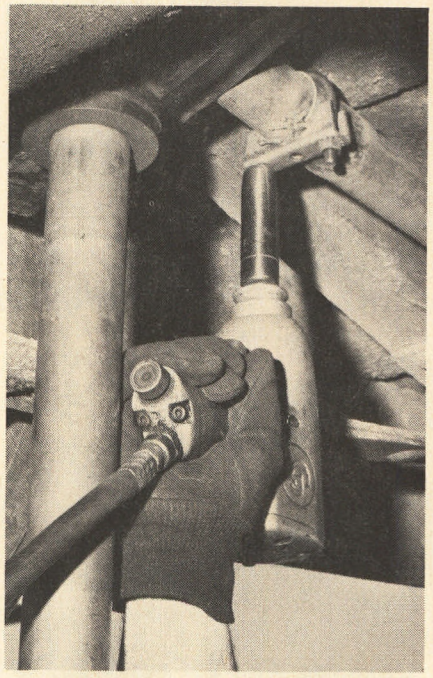
There is one thing to remember: You cannot "repair" a faulty exhaust system. Any "michael mouse" attempts at plugging holes or making temporary repairs could create a fire hazard or cost you your life, either from carbon monoxide inhalation or from the drowsiness it can cause at the wheel. Replace worn-out components and visually check the system from time to time while the car is being serviced. And watch that heat valve; if you keep it free, your exhaust system will last twice as long—to say nothing about how much better the car will run.

EXHAUST GAS RECIRCULATION

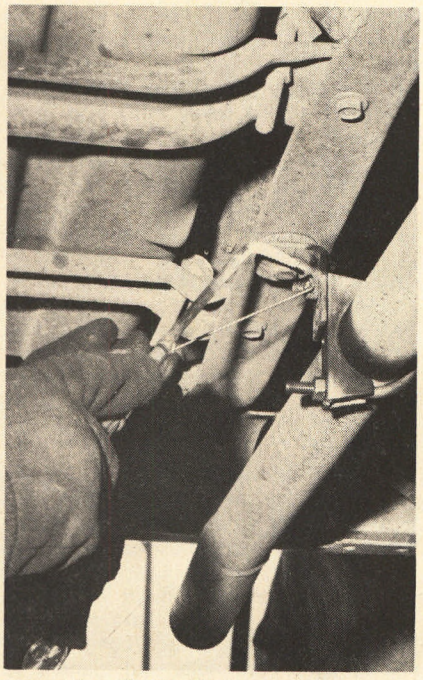
In theory at least, exhaust systems on 1973 cars should have a longer life because of the reduction of nitrogen oxides in the exhaust brought about by the introduction of the Exhaust Gas Recirculation system. EGR, as it's known, first appeared on 1972 Buicks, and variations of the system are now in use on all domestic '73 cars. As high combustion temperatures cause nitrogen and oxygen to combine, nitrogen oxides form and pass through the system into the air as a pollutant. EGR simply recirculates exhaust gases through the engine intake manifold and into the cylinders where they combine with the air/fuel mixture for combustion. Since exhaust gases are relatively inert and burn at a considerably lower temperature than the air/fuel mixture in the cylinder at the moment of peak combustion, they dilute the combustion chamber charge, slowing the process of combustion and so reducing the combustion temperature to a level where formation of nitrogen oxides is inhibited. EGR compliments the AIR system that's been used for several years now to reduce the hydrocarbon and CO_1 content of exhaust gases, and as the smoggy state of the art now exists, Detroit's gone about as far as it can go until the catalytic muffler is perfected.

A vacuum-operated recirculation control valve generally mounted at the rear of the engine manifold and connected to an inline temperature control valve is the heart of the EGR system. Vacuum supplied by the carburetor is blocked by the temperature control valve whenever underhood temperatures are below 55° F. When the throttle valves are opened beyond the idle position, vacuum is applied against the EGR valve actuating diaphragm. As the diaphragm moves up against spring pressure, it opens the exhaust gas intake valve, allowing exhaust gases from the manifold exhaust crossover channels to be drawn back into the engine intake. The valve remains closed during idle and deceleration, when excessive exhaust gases added to the air/fuel mixture would cause rough engine idling.

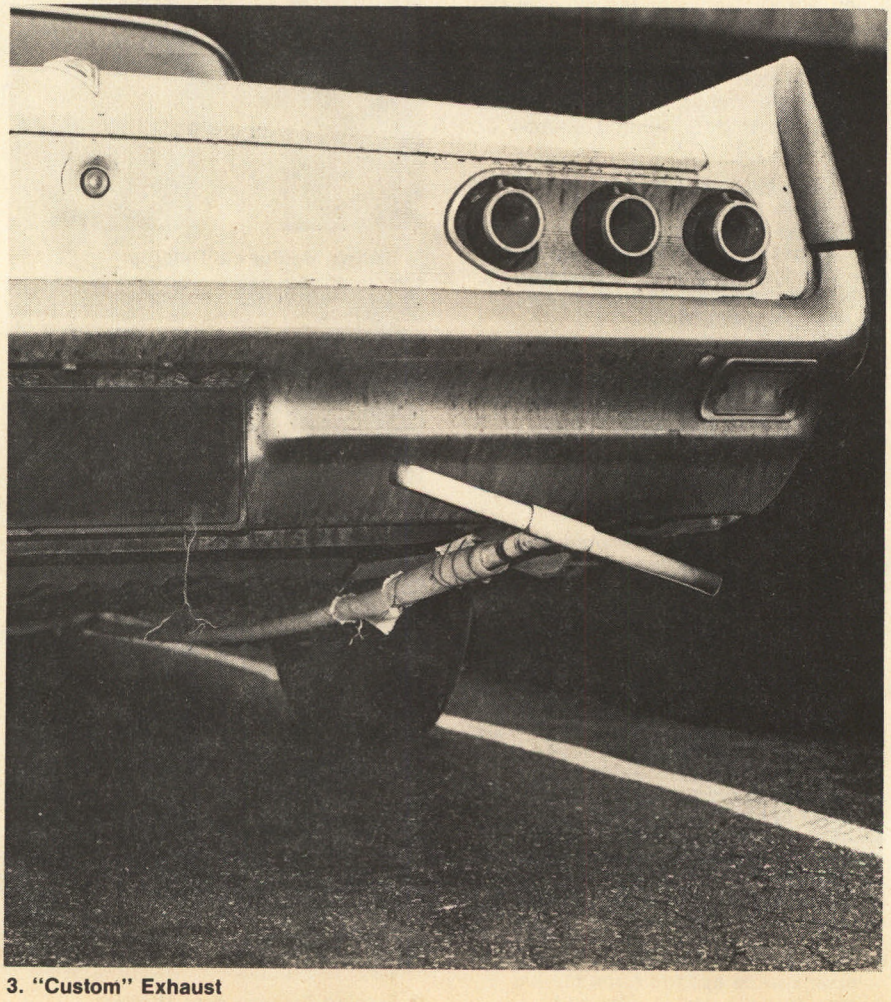
You can't disassemble or service the EGR valve or its companion temperature control valve, but both can and should be checked periodically for correct operation. This is done by opening the throttle to 1500 rpm; at this point, the valve



1. Tightening C-Clamp



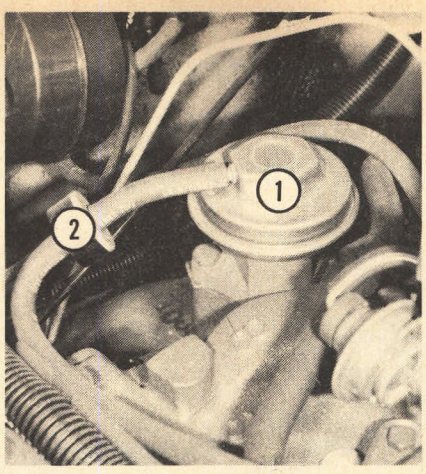
2. Tacking Nut to Stud



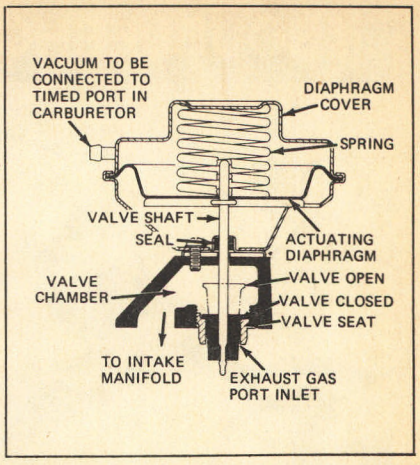
3. "Custom" Exhaust

stem should move downward when the vacuum line is disconnected, and upward when it's connected. If it doesn't move at all, replace the unit. While this movement can be felt by putting your hand under the rear of the valve, this is rather tricky as you're likely to get a good burn from either the hot valve or the engine manifold. It's much smarter to hold a pocket mirror behind the valve where you can watch its operation as you remove and replace the vacuum line. Check the temperature control valve when the engine is cold; this assures that the underhood temperature will be under 55° F. Start the engine and open the throttle to 1500 rpm. If the EGR valve stem moves as you increase the engine idle to this speed, the control valve should be replaced.

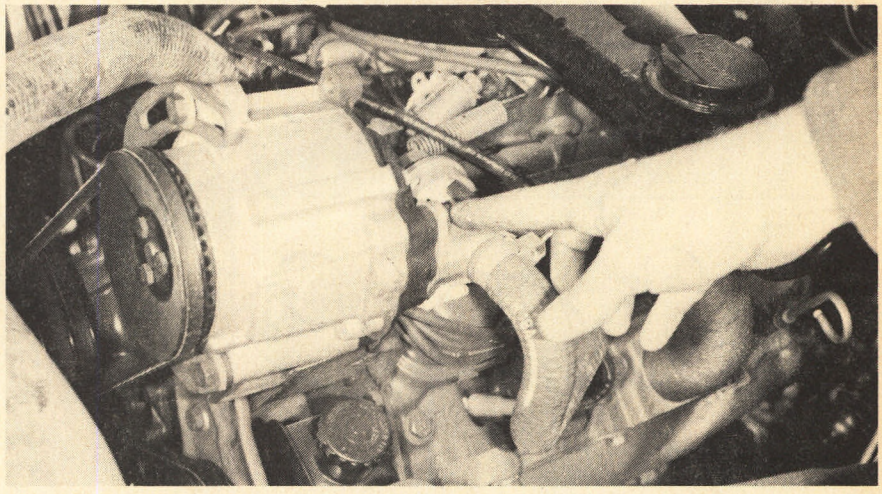
Maintenance of the valve is important, especially as the car gets older. If the valve sticks closed, you won't be able to tell from the engine's performance whether or not the system is functioning properly. And if it sticks in the open position, you'll have a great deal of difficulty in starting the car and keeping it going at lower engine rpm's—such is the price of progress.



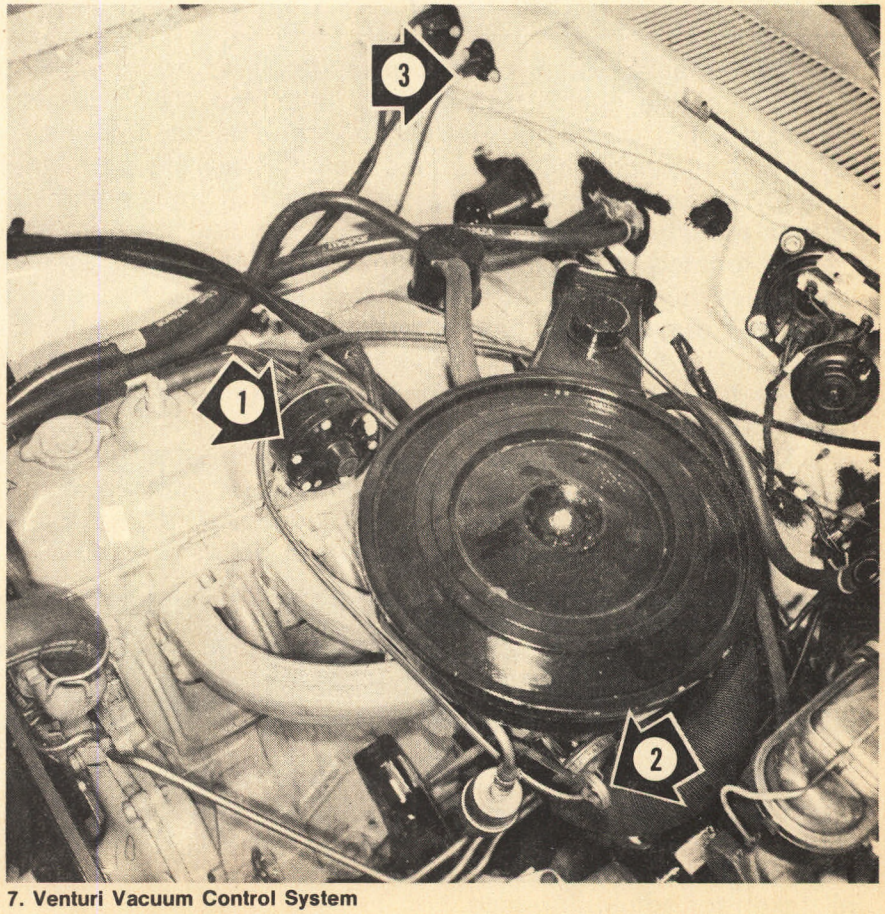
4. E.G.R. and Temperature Control



5. Cross—section of E.G.R.



6. A.I.R. Diverter Valve



7. Venturi Vacuum Control System

1. You can use a ½-in. socket and short extension attached to a ratchet to cinch down the nut on the end of the U-clamp. Make sure the nut is securely tightened so it won't work loose and cause a rattle.

2. The pros make sure the nut will never back out by tacking it to the stud. However, it's hacksaw time when an "R 'n R" is necessary.

3. You don't often see an exhaust tip like this—and we can all be thankful for that. It looks like a water pipe with a "T" in the end that squirts in both directions at once.

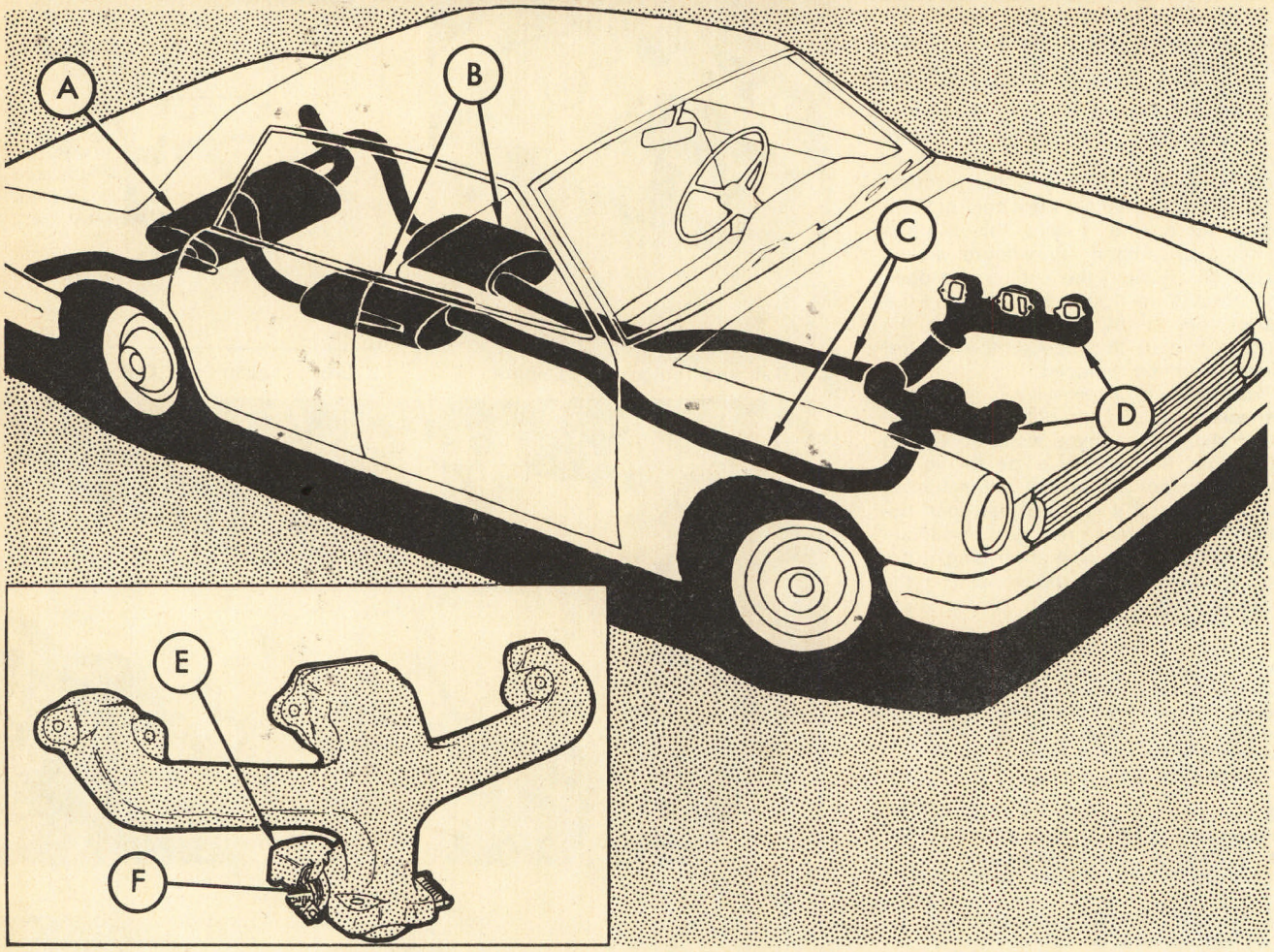
4. E.G.R. valve (1) is mounted on right rear of '73 Buick engine manifold; exhaust gas intake port connects to intake manifold exhaust crossover channel where it picks up exhaust gases. Valve is operated by vacuum from the carburetor and is controlled by the inline temperature control valve (2).

5. Cross-sectional view of Buick E.G.R. valve shows how the system works. If valve sticks in open position, starting the car becomes a major problem.

6. A.I.R. diverter valve attaches to rear of air pump and opens during sudden deceleration to pass air from pump outside the system. Bolts on this '73 Buick pump are torqued to 120-160 in.—lbs., but vibration causes them to work loose, so tighten bolts every few thousand miles.

7. The venturi vacuum control system used on Chrysler, Dodge and Plymouth cars differs from the ported control system such as Buick's in that an amplifier (1) is necessary to increase carburetor-provided vacuum to operate the E.G.R. valve (2). Temperature control valve is firewall-mounted (3) and connected to amplifier unit. E.G.R. valve is on left side of engine in various locations, depending upon engine size.

TROUBLESHOOTING THE EXHAUST SYSTEM



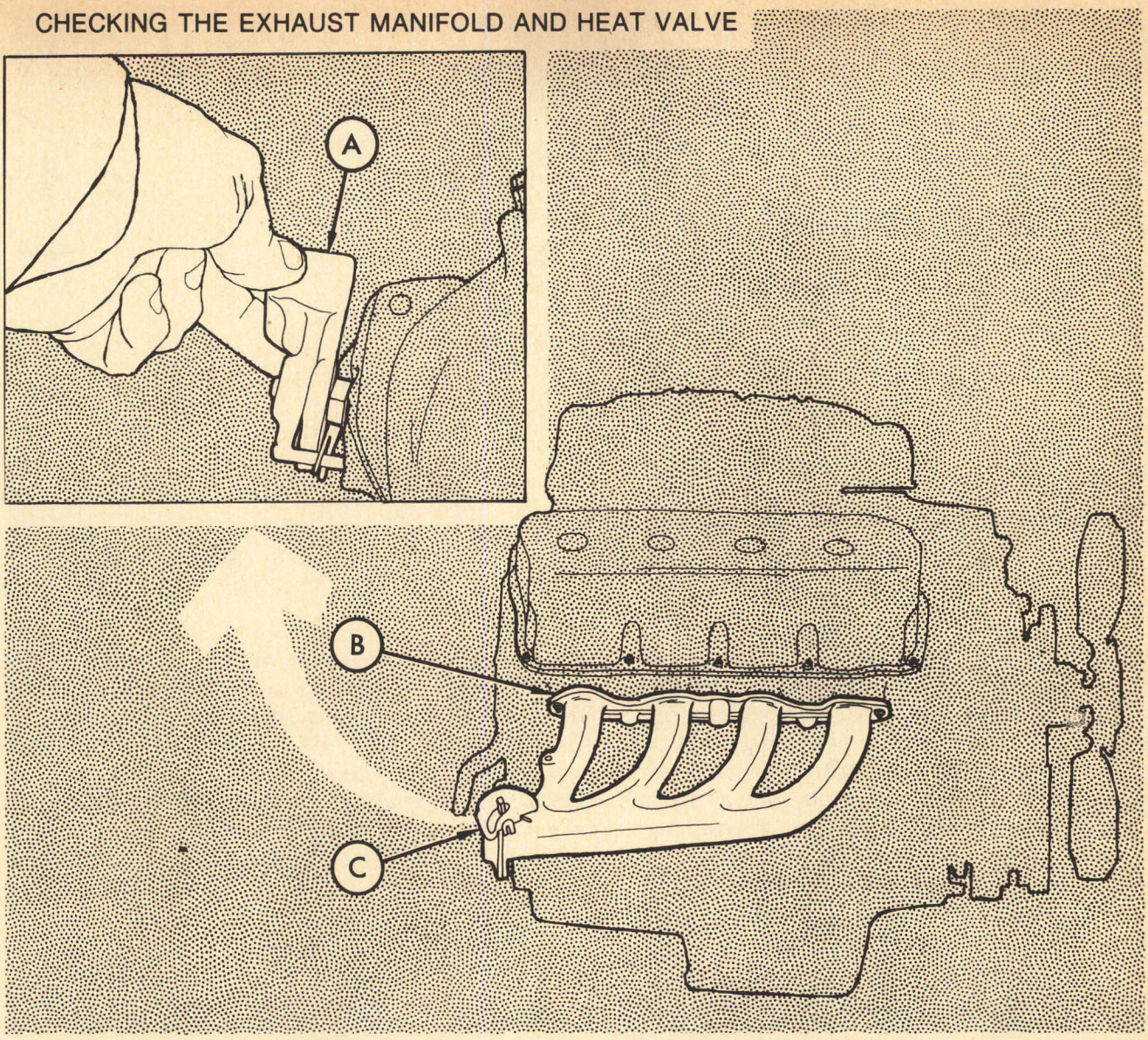
The exhaust system carries gases left over from combustion away from the engine and to the back of the car to be released in the air. The exhaust system begins with the exhaust manifold (D), a cast iron duct which connects each of the exhaust ports in the cylinder head to the exhaust pipe (C). At some point along the pipe, there is a large canister called the muffler (B), which reduces the noise level of the engine's exhaust output. On some cars, a further reduction of the noise level is handled by a resonator (A), another type of muffler usually located near the end of the pipe. Many engines use a small valve called a manifold heat valve (E). When the engine is first started, this device routes some of the hot gases through a duct to the intake manifold to warm the manifold and insure better vaporization of the fuel. The manifold heat valve is operated by a thermostatic spring (F) in much the same way as the carburetor choke. As the engine warms up, the spring slowly closes off the opening to the intake manifold.

The most serious problem that can be created by the exhaust system is the introduction of exhaust gases, primarily carbon monoxide, into the inside of the car through a leaky pipe, muffler or connection. Carbon monoxide gas is odorless, tasteless and highly toxic. Small doses cause sleepiness or nausea; larger doses are fatal.

WARNING: NEVER RUN AN AUTOMOBILE ENGINE IN A CONFINED SPACE SUCH AS A GARAGE. WHENEVER A LEAK IN AN EXHAUST SYSTEM IS SUSPECTED, MAKE ALL CHECKS AND TESTS OUTDOORS.

The exhaust system must do its job well in order for the engine to get good performance and gas mileage. A restriction, such as a large dent in a pipe, can cause problems which may seem to be symptoms of other problems, such as carburetion or internal engine troubles. Broken or loose exhaust pipe clamps and hangers can cause noises which can also be mistaken for something else.

CHECKING THE EXHAUST MANIFOLD AND HEAT VALVE



The exhaust manifold seldom causes any problems, but exhaust leaks can occur at the point where the manifold is bolted to the cylinder head or block of the engine. Leaks can usually be found by a visual check of the gasket between the manifold and head (B). Signs of leaking are carbon streaks or discoloration of the metal or the gasket. On V-8 engine cars, be sure to check both manifolds (left and right). Look for cracks in the cast iron around the bolts which hold the manifolds to the heads. Also check the bolts to see if they are tight. Small leaks can show up if manifold bolts loosen due to vibration.

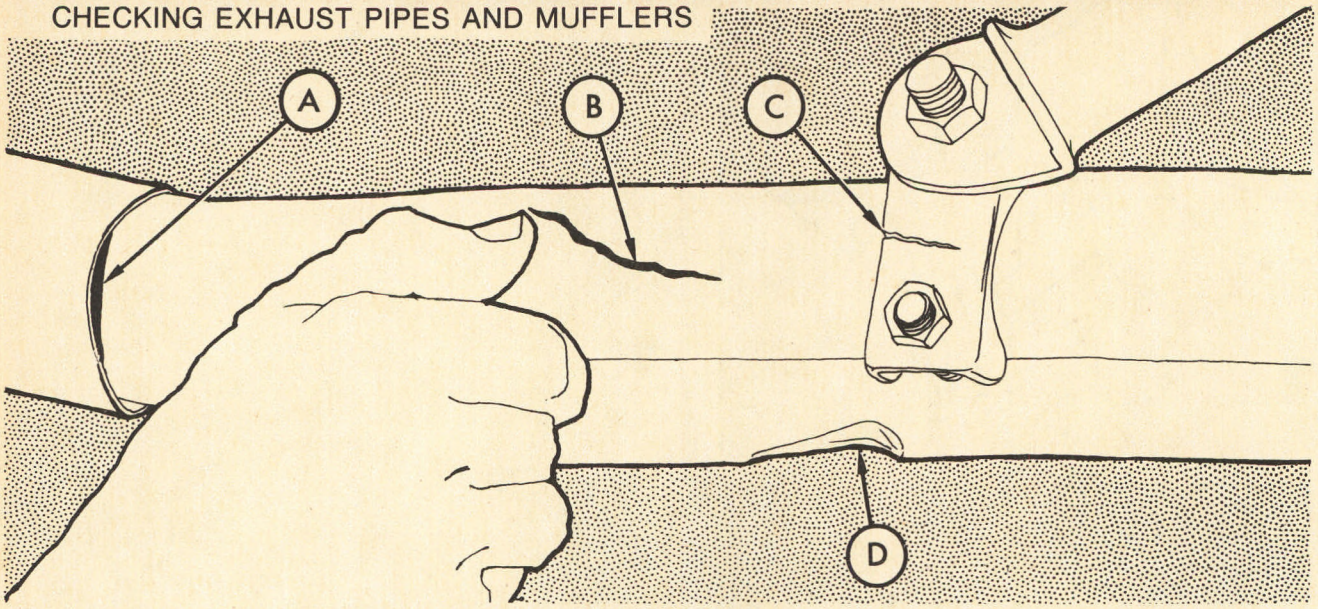
The manifold heat valve (C) can be checked by grasping the balance arm (A) and moving the valve through its range. It should move freely and without undue force being applied. For a further check, note the balance arm's position when the engine is cold, then start and run the engine until it reaches normal operating temperature and recheck the position of the balance arm.

WARNING: BE CAREFUL WHILE WORKING ON THE MANIFOLD HEAT VALVE. EXHAUST MANIFOLDS AND PIPES CAN BECOME EXTREMELY HOT WHEN THE ENGINE IS RUNNING. IF THE ENGINE HAS BEEN RUN, GLOVES AND A LONG-SLEEVED SHIRT MAY BE NECESSARY TO AVOID BURNS.

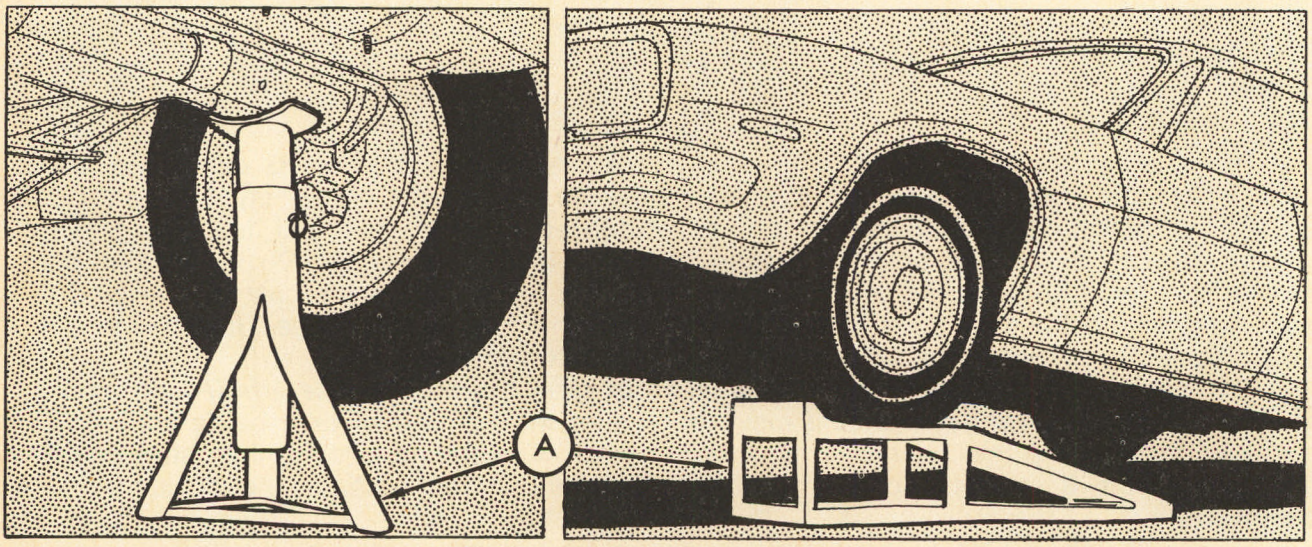
If the manifold heat valve is stuck, it can often be freed by the use of a hammer. Just tap it lightly until it moves freely. A high-temperature silicone grease will help. This grease can usually be purchased at any auto parts store, or you can obtain it from your dealership's parts department. Do not use normal oils or grease, because they will smoke or catch fire when the engine is hot.

TROUBLESHOOTING THE EXHAUST SYSTEM

CHECKING EXHAUST PIPES AND MUFFLERS



A detailed check of the entire length of the exhaust(s) should be made. Look for dents (D), holes (B), broken brackets (C) and loose connections (A). Be especially careful to check out any areas which look rusty or corroded. These are the first signs of a hole developing in the pipe. Use a screwdriver to lightly probe all suspected spots. If the problem is serious, the screwdriver will break through the pipe and the pipe should then be replaced. Because of their internal design, which slows exhaust gases down, mufflers are especially prone to rusting and corrosion. Check them carefully. Grab the exhaust pipe at various parts and shake it. It should move on the rubber suspension hangers, but should not come in contact with any other part of the chassis.



WARNING: DO NOT CRAWL UNDER ANY AUTOMOBILE UNLESS IT IS ON GOOD AXLE STANDS, RAMPS OR A HYDRAULIC HOIST. SERIOUS OR FATAL INJURY COULD RESULT IF THE CAR FALLS.

When examining the exhaust system (or any other part of the underside of the car), make sure that it is safely raised. Good axle stands or ramps (A) should be used. Don't use a bumper jack to lift the car. Get a good quality hydraulic floor jack from a tool rental outfit or put the car on a hydraulic lift at a service station. Also, be careful when handling the mufflers and exhaust pipes. If the car has been run, they can be very hot and serious burns can result. Wear gloves.

The Catalytic Converter

For years, the exhaust system has consisted of one or two exhaust manifolds, several feet of bent tubing, mufflers and maybe a resonator or two. It remained virtually unchanged until 1975 when a strange new component was added. It's called a catalytic converter and its purpose is to reduce polluting emissions before they leave the tailpipe.

In recent years, Detroit has reduced emissions by dropping engine compression and by attaching numerous add-on devices. It takes time and lots of money to redesign an engine and in the meantime, these devices have sufficiently cleaned the exhaust but only with a great sacrifice of performance, engine efficiency and most important, fuel economy. For '75, the converter was introduced to recover some of this lost performance and economy while further reducing pollutants. The device is not required by law but it is included on all GM cars and GM trucks under 6000 lbs. GVW regardless of state. Ford, Chrysler Corp. and AMC include them on all their California-sold cars (except for a few 6-cylinder Jeeps) and all California-sold trucks under 6000 lbs. GVW. All other states get the converter but only with some engines.

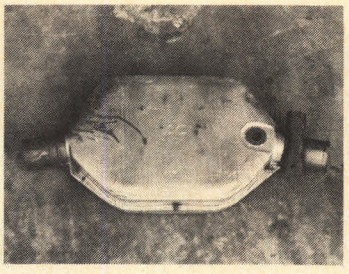
The converter, resembling a flattened muffler, is located beneath the passenger's floor. Exhaust gases exit the manifold, flow through the exhaust pipe and into the converter and once inside, a catalyst of platinum and palladium pellets combine with the unburned hydrocarbons (HC) and carbon monoxide (CO) of gasoline. A chemical reaction takes place, and the HC and CO are converted into hopefully harmless gases for a substantial reduction (56-72% lower HC, 61-77% lower CO). The exhaust then leaves the converter, goes through the muffler and out the tailpipe.

The converter permits a richer air/fuel mixture at the carburetor for improved low-speed response and a smoother idle. Consequently, this increases HC and CO levels at the engine but these extra pollutants are consumed by the catalyst before reaching the air. Prior to '75, oxides of nitrogen (NOx) were controlled by retarding the ignition timing, but raising the HC and CO lowers NOx and for that reason, ignition timing has been advanced for converter-equipped cars. Advanced timing has improved low-end performance, drivability and economy.

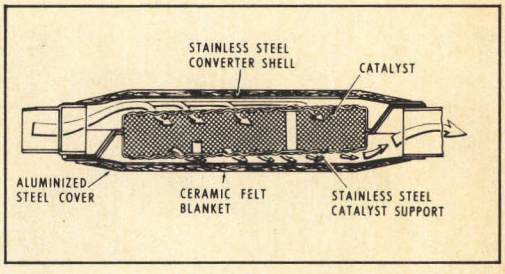
The converter seems to be a pretty good device but shortly after its introduction, owners of converter cars noticed the smell of sulphuric acid drifting from the tailpipe. The catalyst certainly does its intended job but the pollutants it creates may be more harmful than those it is designed to destroy. For that reason, the converter may be short-lived but for those cars so equipped, there are certain precautions to be taken. A decal near the gas cap reminds you to use only unleaded fuel, and the gas tank filler neck has been made small to accommodate only the smaller nozzle of the unleaded pump. The lead causes a gradual deterioration of the catalyst and it takes only two tankfuls to destroy its effectiveness. The converter doesn't blow up and the car doesn't stop but emissions are no longer reduced.

Another thing to avoid is any situation where large quantities of raw fuel are allowed to reach the converter. Ignition misfire creates raw fuel and for that reason, high-voltage electronic ignitions are used on all converter cars. This has reduced the chance of misfire and increased intervals between plug changes, but plugs should be replaced at the first sign of fouling because one or two bad ones can destroy a $150 converter. Dynamic compression tests should be made quickly and no more than one plug should be shorted at a time.

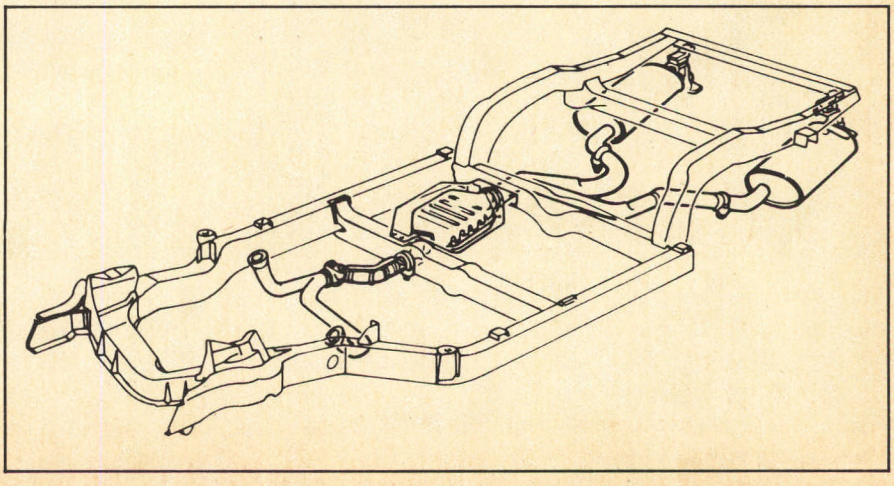
Push-starting a car can cause excessive flooding and/or backfiring so this should be prevented. Anything that requires prolonged cranking—like jump starting with another battery—should be avoided. Fuel additives or cleaners tend to loosen up carbon deposits that could clog the converter, and the chemicals may harm the catalyst. Low-speed, full-power dyno testing should be avoided and prolonged running should be done only in a ventilated area. The converter holds a lot of heat so allow it to cool before working around it. Correct engine dieseling problems and to ensure reduced emissions, have the converter checked periodically.



1. The catalytic converter is a standard item on most U.S. cars for 1975. If certain precautions are taken, the converter should last for 50,000 miles. When replacement becomes necessary, a plug on the underside can be removed and the old pellets can be sucked out and replaced with new ones.



2. The outer covering of the converter is aluminized steel followed by a blanket of ceramic felt insulation. Beneath this is the converter shell, which is made of stainless steel. In the center is the all-important catalyst of platinum and palladium pellets. The exhaust gases enter the converter and flow through the catalyst. The catalyst reacts chemically with HC and CO to create carbon dioxide and water vapor.



3. The exhaust pipes ahead of the converter are usually made of stainless steel. Cars with dual exhaust use only one converter as shown in this drawing of a Corvette system.

Clutch & Flywheel

The clutch is a weak link, not because of any manufacturing oversight or lack of engineering but because it is designed that way. The car makers have tactfully admitted this by their refusal to warranty the clutch under any circumstances. They will guarantee that it was manufactured right and installed correctly, and after that you are on your own. Actually a clutch is designed to wear out; how fast it wears out depends on you, the driver.

A clutch is nothing more than a rotary coupling device between the engine and transmission that can slip while it's gradually picking up the load of moving a car—and then hook up "solid" when the car gets rolling. Also, we need a way to disconnect the engine from the rear wheels to smoothly shift gears, allowing the car to be stopped without putting the transmission into neutral. The clutch does this.

The clutch mechanism is quite simple. You have a friction disc that is splined to the transmission input shaft. This disc is squeezed between the engine flywheel and a heavy "pressure plate" inside a clutch cover or housing which is bolted to the flywheel.

The pressure plate is pressed forward by some type of spring arrangement—either a series of small coil springs or a circular diaphragm spring.

When the clutch disc is squeezed between the pressure plate and the engine flywheel (engaged position), torque is then transmitted to the rear wheels. To disengage the pressure plate (against the spring pressure), we have several release levers that pivot in the clutch cover. These, in turn, are moved by a throwout bearing that rides on a collar extending about halfway up the transmission input shaft, or clutch driveshaft, and is moved by the clutch release fork that is pivoted on the bellhousing.

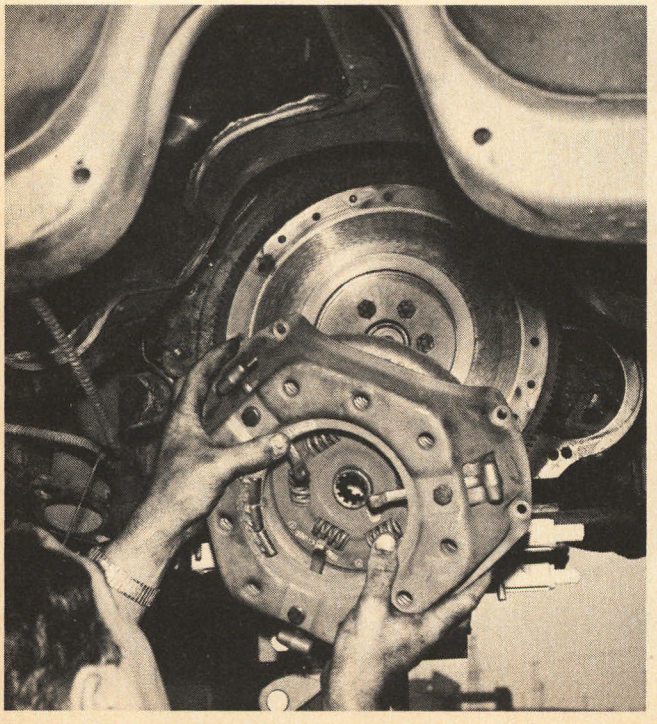
The release fork can be actuated in one of two ways: by a fully mechanical linkage of levers and rods which extends to the clutch pedal in your car, or by what is called a "hydraulic" clutch, which has a master cylinder (similar to the brake master cylinder) which is connected by linkage to the clutch pedal. The clutch master cylinder operates a "slave cylinder" connected to the clutch release fork with a short adjustable rod. When pressure is applied to the slave cylinder, it in turn operates the fork.

ADJUSTING LINKAGE

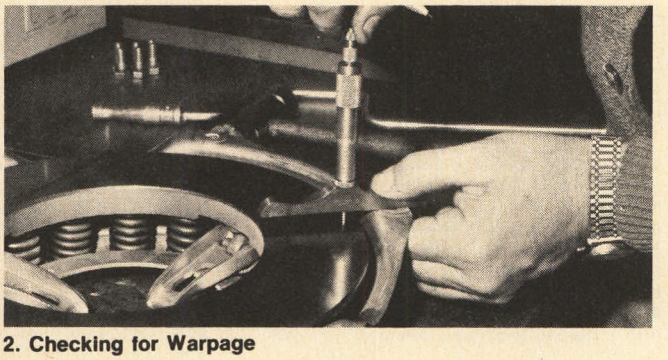
It should be understood that you should *expect* to have to adjust the linkage between the clutch pedal and throwout arm now and then—just to compensate for wear of the friction disc facings. Obviously as the facings wear down and get thinner, the clutch pedal will have to move farther and farther to fully engage the clutch. Eventually you reach a point where the linkage is against the outer stop before the clutch is engaged, and then you will have definite slip.

The adjustment procedure is so simple that you can figure it out yourself. Get under the car and trace down the linkage from the pedal to the clutch release fork on the engine bellhousing. Your adjustment(s) are generally on threaded rod(s) going directly to the clutch release fork—usually there are jam nuts that must be loosened before you turn the rod one way or the other to adjust the pedal freeplay.

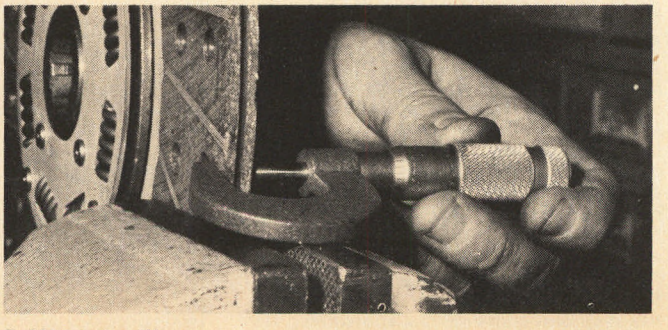
You can determine if the linkage is at fault by checking the amount of "play" (free pedal travel) at the clutch pedal. Using your fingers and holding a ruler next to the clutch pedal, depress the pedal. It should move very easily inward for only about 1 in. This is designated "freeplay." After that it will seem to strike something and you will have to push much harder. The hard point was where the throwout bearing and the clutch release levers contacted. A mechanically operated linkage will have one or possibly two points at which the rods can be adjusted. The threaded adjustment rod(s) usually have locking nuts (or jam nuts) which must be loosened before the rod length may be adjusted. Make two turns on the free travel adjustment, reconnect the clutch rod, and check pedal travel. Repeat this process



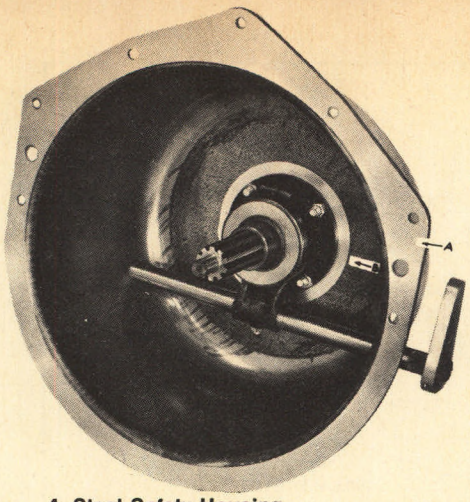
1. Reinstalling Pressure Plates



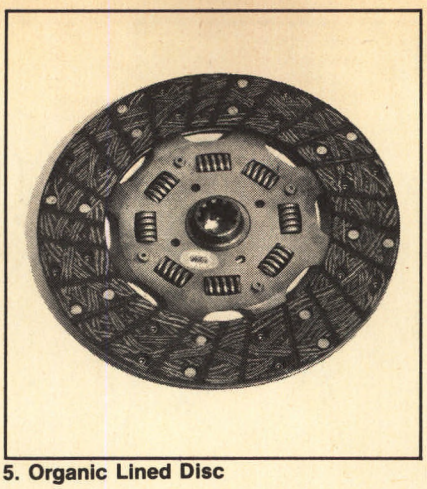
2. Checking for Warpage



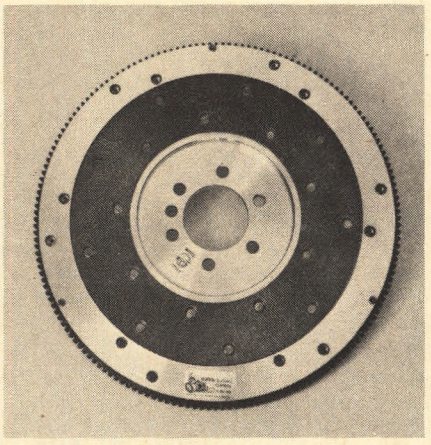
3. Miking for Wear



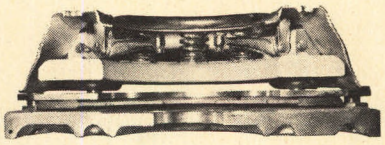
4. Steel Safety Housing



5. Organic Lined Disc



6. Aluminum Flywheel



7. Cutaway Clutch Assembly

1. To avoid clutch chatter, be sure to keep greasy fingers off the flywheel or pressure plate facing during reassembly and reinstallation.

2. If the pressure plate ring on your clutch is badly checkered from heat, or grooved, replace entire unit. You can check ring for warpage by measuring it at all bolt flanges, comparing depth readings of mike.

3. To check overall wear on a clutch disc, use a micrometer. Clamp Marcel-type discs in a vise, gently, so they will compress. Bonded discs can be checked in hand. As lining wears, clutch pressure is reduced accordingly.

4. This hydro-formed steel housing is a product of Lakewood Industries. It is stronger and safer than stock housings and can be used on the street as well as strip. A and B surfaces are parallel machined.

5. This is a Weber Series clutch disc, for street or strip. Organic lining is backed by a .020-in.-thick aluminum heat shield. Springs about hub absorb shock of engagement.

6. A sintered iron replaceable face is used by Hays on their billet aluminum flywheel, which is designed for both street and strip purposes.

7. This cutaway of a clutch and flywheel assembly illustrates how they function. As pressure is placed on fingers, pressure plate moves away from disc, allowing it to float free or become disengaged from flywheel. Thereby power transmission from engine through clutch is stopped.

until you have about 1 in. of pedal travel.

The adjustment of a hydraulic clutch is the same process, with the adjusting link between the slave cylinder and the clutch fork. However, before adjusting a hydraulic clutch, check to see if the fluid is full and "bleed" the line to remove any air. Air in the system will prevent the clutch from operating correctly and smoothly. A hydraulic clutch is bled the same way as a brake system—have someone pump up pressure and hold until you allow fluid to escape and re-tighten the fitting. You should do this three or four times, or until all air has been let out of the system. Keep the master cylinder full during bleeding so that new air does not enter the system, and fill to the recommended level when bleeding is complete. Also check fittings for leaks.

REMOVING THE CLUTCH

More serious clutch troubles will require taking the clutch assembly out of the car. This is a big job—but not impractical or impossible for the beginner or home mechanic who is willing to work.

Clutch removal by pulling the transmission is the shortest and easiest way for an experienced mechanic, but you'll never believe it if you do it yourself because of the many parts that must be disconnected.

On a car with an open driveline, start by disconnecting the universal joint(s) on the driveshaft and removing it. Use a plastic sandwich bag to cover the end of the transmission housing and secure it tightly with a large rubber band. This is to prevent the transmission oil from leaking out as well as to keep dirt from getting in. Disconnect the speedometer cable and transmission shift levers. If the car is equipped with overdrive, disconnect all wires. *Note: Do not attempt to disconnect the overdrive unit from the transmission.* It doesn't come apart this way and *must* be removed as a complete unit. Disconnect the parking brake cable, remove the rear transmission mounting bolts and support the rear of the engine with a jack or blocks. Now remove the bolts that attach the transmission to the flywheel housing. At this point you're ready to remove the transmission, but be careful—some transmissions weigh over 100 lbs., so it's best to have a friend help you lift it out. The transmission must come straight back until the input shaft clears the clutch splines. With the high weight leverage it's easy to have the splines bind in the disc, making removal difficult and possibly bending the disc.

On some cars it will be possible to remove the bellhousing to completely expose the flywheel and clutch unit, or the bellhousing may be part of the transmission case. On others, you will have to be content with the removal of a lower half only or an inspection cover. The lower-half type makes for slower work because you have to rotate the flywheel to expose each set of clutch mounting bolts. Then, when the last bolts are removed, the clutch must be slipped out the bottom and you must be careful so as not to mash your fingers. It's heavy when you only have a small place to hold on to, so don't let it drop on the floor.

Before removing the bellhousing, check to see if there are any brake or clutch linkage brackets that need to be disconnected. If you have a factory manual it will tell you exactly what needs to be disconnected. Also at this time, disconnect the clutch release fork. It's held in place only with a spring or snap-spring clip.

With the clutch and flywheel exposed, take a center punch and make a mark at the edge of the pressure plate cover. Make another mark directly opposite on the edge of the flywheel. This must be done so that the pressure plate and flywheel will be assembled in exactly the same position—because they may have been balanced as a unit. If you don't do this, you won't know where to remount the pressure plate and your engine might be out of balance. It might be well to note here that if you can see that the pressure plate must be replaced entirely, then marking is not necessary.

it has been balanced. In many cases the only thing to do is install the unit and keep your fingers crossed. Luckily, out-of-balance clutches are seldom a problem.

Now, to remove the clutch: There are two ways to do it correctly. The first way, and probably the best, is to use a steel bar (jack handle, etc.) to pry down each clutch release finger, one at a time. As you do this, insert a large nut about ¼-in. in height between the release arm

and the cover. This releases all the pressure from the pressure plate, and all the cover bolts may be removed quickly and easily, in any order.

The second way, and this goes for all diaphragm-type clutches as well as the finger type, is to back off each clutch cover bolt in order around the cover about one turn at a time. You must loosen the bolts evenly so as not to warp the pressure plate. At first they'll turn hard because of the spring pressure, but when they're about halfway out, the release fingers will contact the cover and relieve the pressure. At this point you can just run the bolts right out.

Now that the clutch is out, start inspecting all the components. If the disc is oil soaked, has cracked or broken friction lining, warped or loose rivets at the hub or is worn down to the rivet heads (bonded lining less than 1/32-in. thick on either side), then the disc must be replaced. Also check for broken springs. Springs loose enough to rattle will not cause noise when car is operating. If the pressure plate was at fault, but if the lining is half worn, replacement is recommended to get a new, full life span of the complete unit.

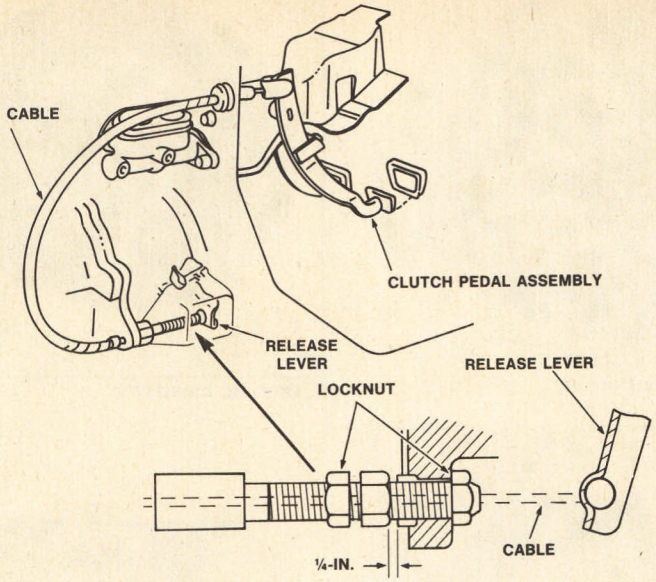
Check the pressure plate for scoring, burn marks (blue color spots) or ridges. Generally, pressure plate resurfacing is not recommended. However, "minor" burn marks and scratches can be removed with crocus cloth.

Examine the flywheel for scoring, burn marks or deep ridges. If any of these problems exist, or if the surface is highly polished, then the flywheel must be resurfaced. Taking a light cut off the face will insure you like-new performance—and it's not that expensive. However, be sure to do this before rebalancing.

The clutch release bearing is prelubricated and *should not* be cleaned in solvent. Instead, wipe it clean and hold the bearing inner race and rotate the outer race while applying pressure to it. If the bearing rotation is rough or noisy, replace the bearing.

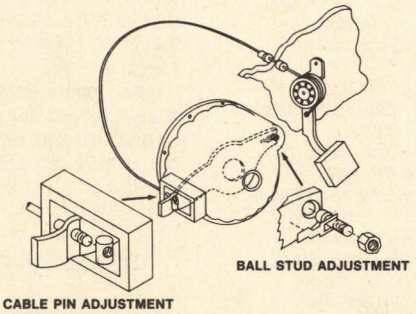
Most release bearing failures are caused by improper clutch pedal adjustments. If the clutch linkage does not have enough free travel, the release bearing will constantly touch the release fingers and will spin whenever the engine is running. Riding the clutch is also a cause for bearing failure. This constant turning heats up the bearing and burns out the lubrication—shortly thereafter you have a bearing failure. Since this bearing is an inexpensive part, it should be replaced. This goes for the pilot shaft bearing (ball bearing or bushing) too. You should check it for wear or roughness, but it's far easier and safer to replace it and forget it.

If the flywheel is off the engine, there is no problem knocking the pilot bearing out. But if the flywheel is still in place on the crankshaft, then the pilot bearing must be removed with a special puller. There are a number of ways to do this, but usually a slide-hammer puller is used which has a hook on the end of it. The hook is inserted in the hole in the pilot



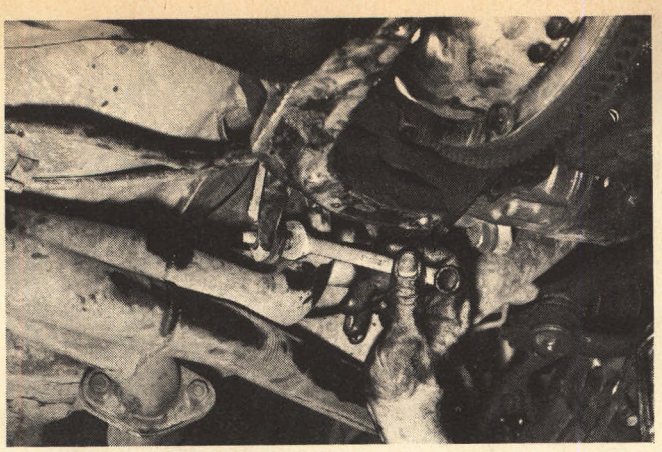
PINTO CLUTCH ADJUSTMENT

Only one adjustment is required, and it is made where the cable goes through the bellhousing. Early models have a locknut on the rear face of the housing, as shown in our illustration. Late models have done away with the locknut, but the adjustment is the same. A quick check on late models can be made by pulling the cable housing toward the front of the car just enough to put the throwout bearing up against the clutch fingers. In that position, the adjustment nut should have ¼-in. clearance from the boss in the bellhousing, as shown. On early models you can't make this check until you loosen the rear locknut. To adjust the clutch, loosen the locknut(s), and turn the adjusting nut until the gap is ¼-in., with the cable pulled forward by hand. When tightening the locknut(s), be sure you don't move the adjusting nut. Ford does not give a pedal free-play specification for Pinto. This ¼-in. cable adjustment is the only specification, and will result in the right amount of pedal free-play.

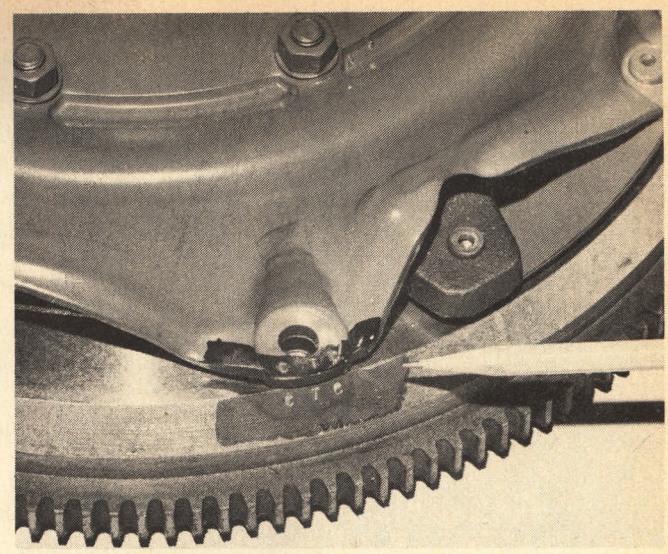


VEGA CLUTCH ADJUSTMENT

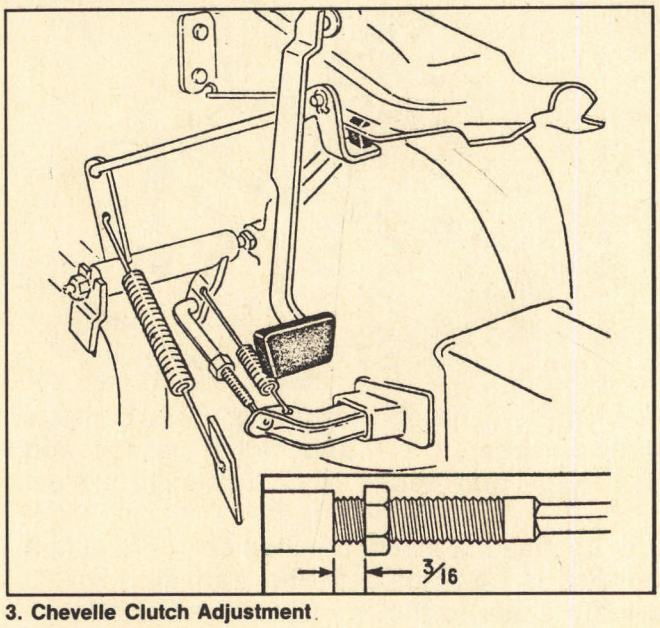
Two adjusting points make the Vega clutch adjustment a little tricky. Ordinarily, the ball stud does not have to be adjusted unless the clutch is changed, but it's possible somebody has turned the stud and gotten everything out of kilter. To adjust the ball stud, you must have a Chevy gauge No. J-23644. It is nothing more than a hook that positions the clutch arm while you adjust the ball stud. You can easily take the measurements off it at your local dealer, and then make your own gauge. In use, the gauge hooks over the front face of the bellhousing and over the clutch fork. While the gauge is holding the clutch arm, the ball stud nut is loosened and the stud screwed in (forward) until the throwout bearing touches the clutch fingers. Tightening the nut locks the stud in position on the bellhousing. Final adjustment for clutch pedal free-play is made with the cable pin. Just screw it up against the clutch fork, making sure that the cable is all the way to the rear, with the pedal up against the rubber bumper. After the pin hits the clutch fork, screw it in about an additional ¼-turn so it drops into the groove in the fork. This will give you about 1-in. free-play.



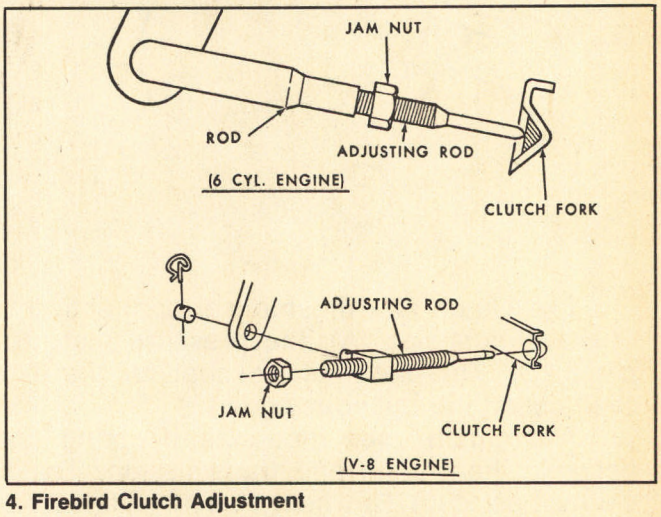
1. Plymouth Linkage Adjustment



2. Balanced Clutch Assembly



3. Chevelle Clutch Adjustment



4. Firebird Clutch Adjustment

1. When you install a new clutch in a car or your old clutch has been in service for awhile, you should readjust the linkage. After adjusting clutch linkage, make sure jam nut is tightened. Free play should be around 1 in. on most automobiles. The linkage shown here is Plymouth.

2. Whenever you have a clutch and flywheel assembly balanced, and it's a good idea, you should put reference marks on the pieces so that they can always be assembled in the correct relationship to each other. A good balancing shop will do this for you as part of the job. Pressure plate, disc and flywheel should be balanced.

3. The clutch adjustment rod on Chevelles is very similar to that on all GM cars. After disconnecting the spring between the cross shaft lever and clutch fork, loosen the push rod locknut. Hold the clutch fork rearward until the throwout is lightly against the clutch release fingers, then adjust rod length until rod just touches its seat in the fork. Now back rod into sleeve 3/16-in., tighten lock nut, and check pedal free play. It should be between ¾-in. and 1 ⅛-in.

4. The clutch adjusting rods on Firebirds are typical of most cars. Spring is removed, jam nut loosened, then rod adjusted until proper free play is achieved at clutch pedal.

bearing on one side of the bearing, and the slide hammer is used to knock the bearing out.

Clutch release bearings, sometimes called throwout bearings, are usually pressed onto the bearing hub. The old bearing can be easily knocked off the hub and a new bearing tapped on with a hammer. However, many mechanics do not bother to do this. They buy the bearing and hub already assembled. It's a little more expensive that way but it saves time and trouble.

Inspect the release bearing hub for burns or scratches. The release bearing should slide freely. If you're in doubt or you feel a scratch, polish it out with crocus cloth. Coat the release bearing hub with a thin coat of oil before assembling release bearing and hub assembly.

With your new disc in hand, check it out on the splines of the input shaft. It must slide smoothly. If it doesn't, see what's wrong. Crocus cloth can and should be used to polish up the spline to a smooth finish.

If your clutch disc was ruined because of an oil leak, you must determine the cause—engine or transmission—and get the leak repaired before assembly. If you don't, your new parts will last only a short time.

Now you are about ready for reassembly. Be sure your hands are free of grease for the initial assembly. A greasy fingerprint on the flywheel or pressure plate facing or clutch disc can ruin a good clutch job. It can cause chatter. Clean the flywheel and pressure plate faces just before assembly.

The assembly process is the reverse of the removal operation. Start by installing the flywheel and putting a thin coat of bearing lubricant inside the pilot bushing or bearing race.

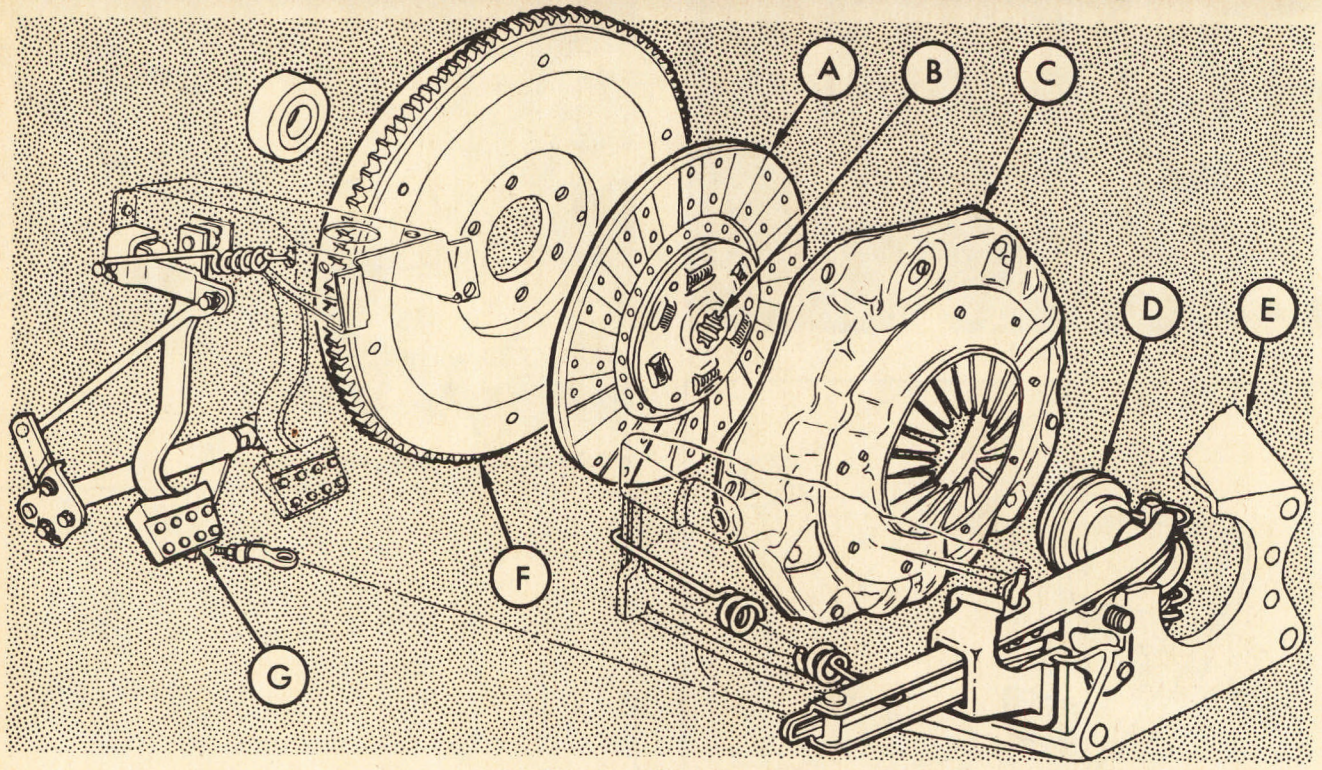
To align the disc you're going to need some kind of pilot shaft. You can't do it "by eye." There are special tools for this, but the most inexpensive way is to cut an input shaft off a junk transmission to use as a guide.

Now hold the pressure plate and disc in close location and push the alignment shaft through the disc spline and into the pilot bearing. Line up your centerpunch marks and start bolting up the pressure plate, using the same procedure you followed during removal.

It should be noted here that both the flywheel and the clutch bolts must be torqued to factory specifications. Once the pressure plate is torqued down, remove the spacers and pull out the alignment shaft.

Lubricate the clutch release fork at the pivot points and then complete the assembly. Remember, you'll need help installing the transmission, and you must be extra careful not to bend the disc and ruin your clutch job.

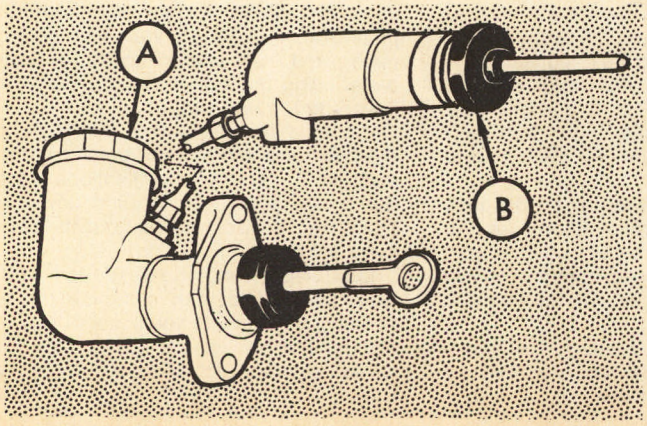
TROUBLESHOOTING CLUTCHES



The clutch is a mechanical connection between the engine and transmission. It consists of the clutch disc (A), the pressure plate (C), throwout bearing (D) and clutch linkage and pedal (G). This assembly, except for the external linkage and pedal, is contained in a steel shell called the bellhousing (E).

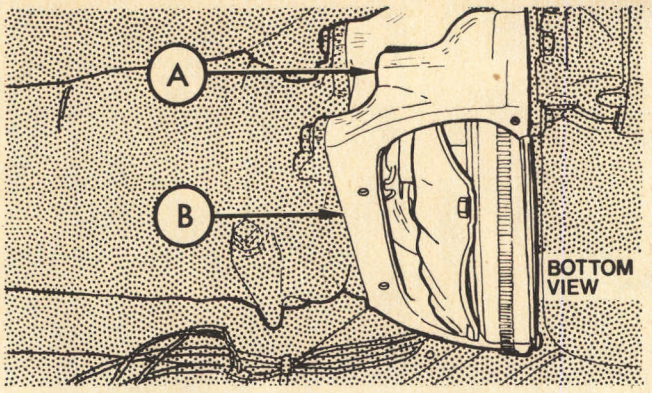
The clutch uses friction and spring pressure to make a solid mechanical connection between the engine and transmission. The clutch disc is connected to the transmission. Its center has teeth (B) which fit over splines on the input shaft in the front of the transmission. The clutch disc can move forward and back on the shaft but cannot rotate without rotating the shaft. The clutch disc is contained inside the pressure plate, which is bolted to the flywheel (F). When the clutch pedal is depressed, it is no longer forced into contact with the clutch disc by its heavy springs. This takes the pressure off the disc, and the flywheel can rotate without causing the disc to turn. When the pedal is released, the heavy springs of the pressure plate force the disc against the flywheel, causing it to "lock up" and turn with the flywheel. This in turn causes the input shaft to turn, transmitting the power of the engine to the transmission, through the driveshaft and on to the rear wheels to make the car move.

The clutch disc is designed to slip slightly when it is engaged, to make a gradual engagement instead of a sudden one. In this manner, the car can start forward or backward smoothly, without jerking. The force of the pedal is transferred to the pressure plate through a bearing called the throwout bearing. One part of the bearing contacts the rotating pressure plate; the other rests against the stationary clutch arm, which is part of the linkage.



Some manufacturers do not use a mechanical linkage between the clutch pedal and the clutch arm. They substitute a hydraulic system similar to that used on brakes. In the hydraulic system are a master cylinder (A), a slave cylinder (B) and a hydraulic line connecting the two. When the clutch pedal is depressed, the master cylinder sends a high-pressure movement of hydraulic fluid through the line to the slave cylinder. The slave cylinder matches the pedal movement to operate the clutch arm in exactly the same manner as the conventional clutch linkage would.

TROUBLESHOOTING CLUTCHES



Wear, misadjustment or oil contamination are the most common causes of clutch malfunction. The clutch can be visually examined by removing an inspection plate (B) on the underside of the bellhousing (A). Without expert knowledge of what to look for, the chances of seeing any damage other than oil leaking onto the clutch are slim. Most methods of troubleshooting the clutch can be accomplished without visually examining the clutch itself.

CLUTCH SLIPS

If the clutch slips (does not make a good connection between the flywheel and the pressure plate), it usually shows up as a slight bucking of the car and increases in engine rpm while the car is in motion. To check, set the emergency brake tightly. Press down on the gas pedal until the engine is running at about the same rpm it would be at 30 mph. Depress the clutch and put the transmission in third or fourth gear. Let the clutch pedal out. If the clutch is not slipping excessively, the engine will stall.

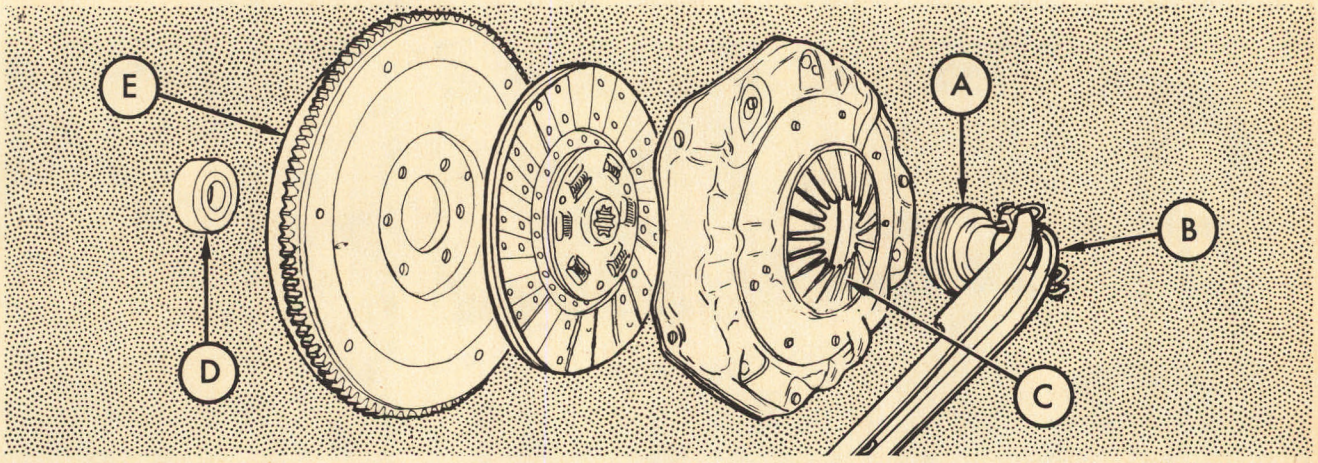
The causes of a slipping clutch are: worn clutch lining, weak pressure plate springs, sticking clutch release levers on the pressure plate, clutch linkage out of adjustment. For all but the clutch linkage, corrective action requires that the clutch be removed. For clutch linkage adjustment, see your shop manual.

CLUTCH CHATTERS

Clutch "chattering" occurs when the clutch slips in short, jerky movements when being engaged (let out). The most common causes of the problem are: oil or grease on the clutch lining (caused by a leak in the rear main oil seal around the crankshaft), a glazed clutch lining from overheating, a warped pressure plate or clutch disc, loose or broken engine mounts or loose universal joints or transmission mountings. All require removal of the clutch to correct (see your local mechanic or shop manual).

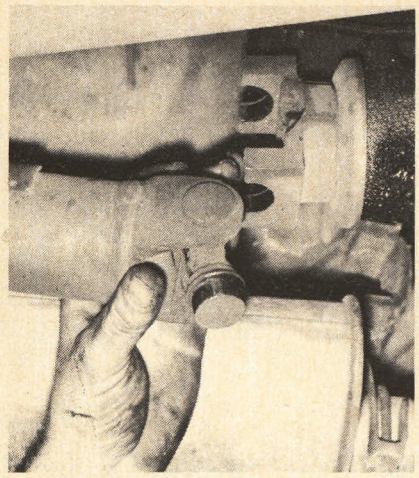
CLUTCH NOISE

Clutch noises are often confused with other engine noises, but are generally heard only when the clutch is disengaged (pedal pushed in).

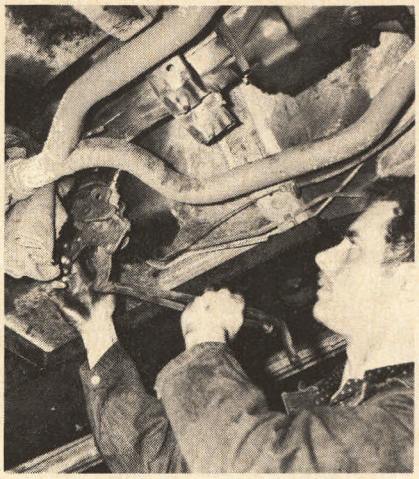


The two most common causes of clutch noise are the bearings: the throwout bearings (A), which ride between the clutch arm (B) and the fingers on the pressure plate (C); and the pilot bearing (D) or bushing. The pilot bearing is fitted in the center of the flywheel (E). It supports the tip of the transmission input shaft and maintains precise alignment of the shaft with the centerline of the crankshaft. Both bearings can cause a clattering sound if worn, and the clutch assembly must be disassembled to remove them. (See your shop manual or your local mechanic for instructions.)

HOW-TO: Installing a Clutch



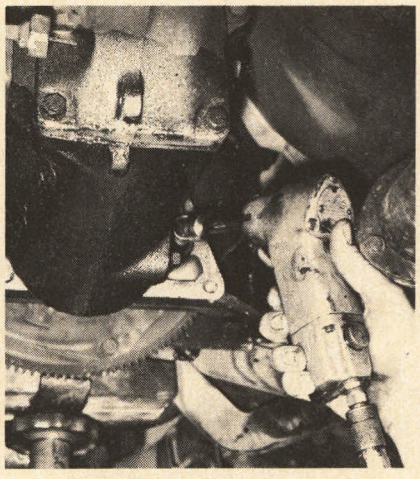
1. First operation involved in pulling a transmission so you can replace the clutch is to remove the driveshaft. Start at rear U-joint.



2. On most cars with floor shifts, you'll have to drop the shifter as a unit, for the simple fact that it is bolted to the side of the transmission.

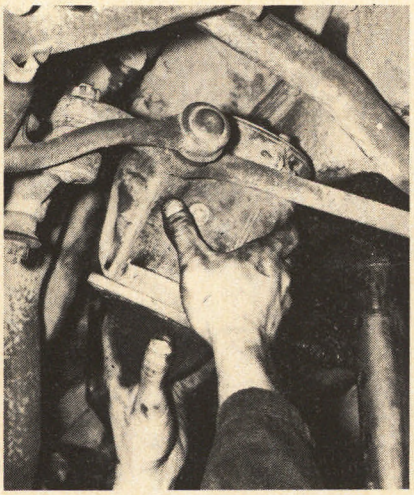
3. On transmissions with removable pan on bellhousing, pull the pan. This saves you the trouble of having to remove the entire housing.

4. Raise rear of engine slightly with jack to take pressure off crossmember, then remove crossmember. Be sure engine is supported firmly and safely.

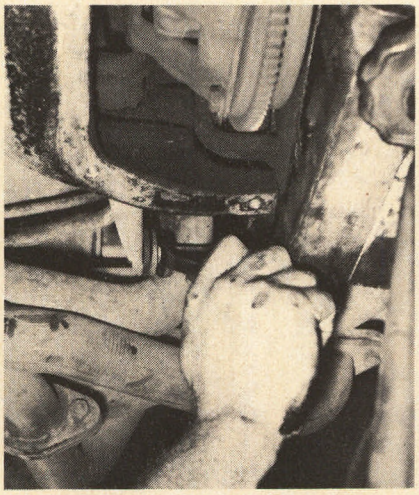


5. Once the crossmember is out and speedometer cable and all linkage is disconnected, you can proceed with removing transmission itself.

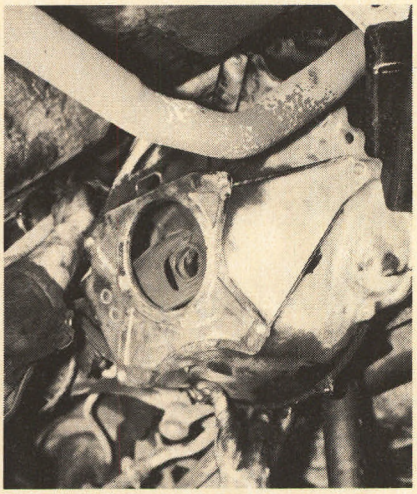
6. After removal of all linkage, rear crossmember, shifter, etc., it is possible to remove a manual trans by hand. Just don't drop it though.



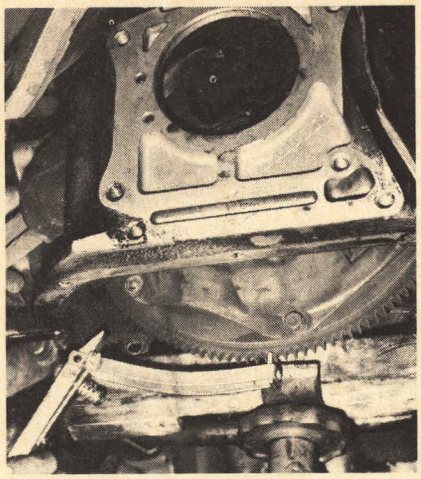
7. If your starter bolts to your bellhousing instead of the engine, you'll have to remove the starter before you can take off the bellhousing.



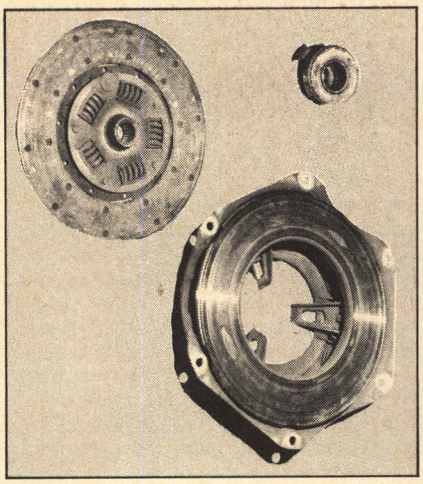
8. Next operation involves removing linkage at clutch throwout arm. At this point, clutch and/or housing is ready to be pulled from car.



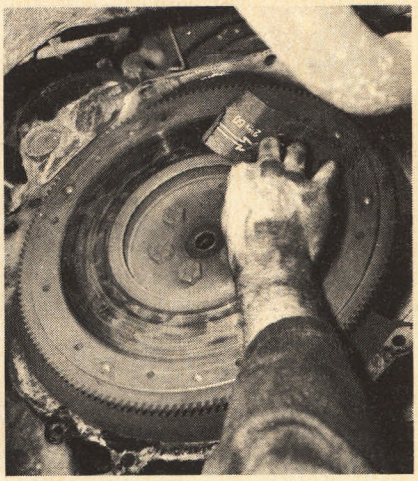
9. After using a long extension and maybe a flex-socket to get upper bolts at rear of engine, you can remove the bellhousing (heavy!).



10. A special ratcheting tool is used to rotate flywheel around so pressure plate bolts can be pulled. A screwdriver will work here, too.

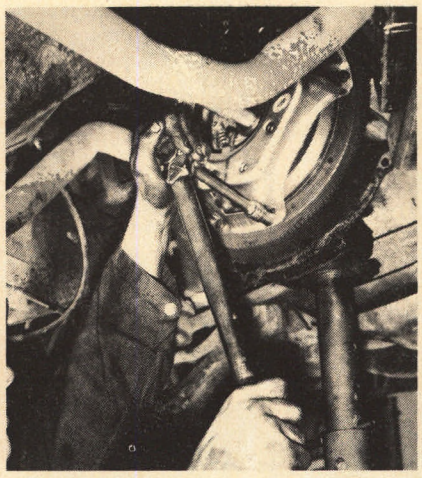


11. This clutch assembly came out of a MoPar and was slipping badly at 28,000 miles. Pressure plate face is really worn. All parts replaced.

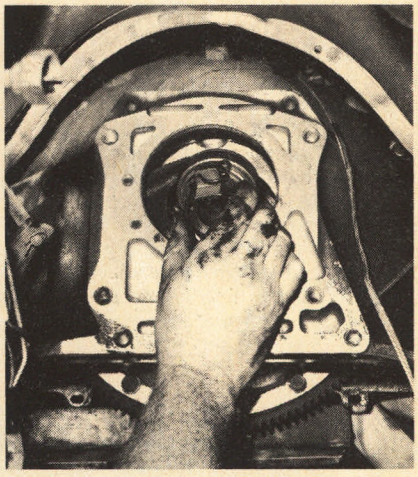


12. Sandpaper can be used to remove the glaze from the flywheel facing, but if the surface is irregular, you should get the flywheel face ground.

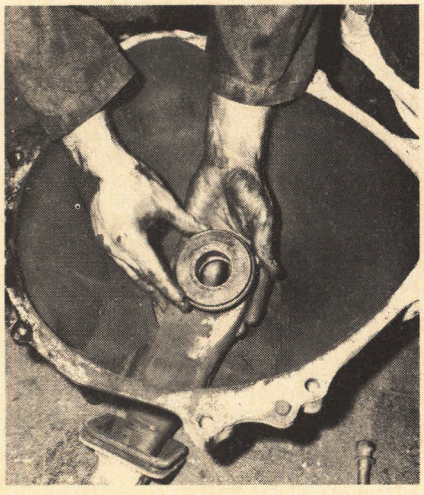
13. Either the front shaft of an old transmission or wooden pilot is used to line up the disc while you start the bolts in around clutch.



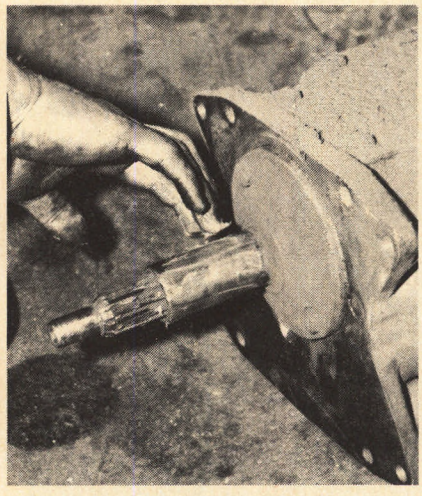
14. When all the bolts are started and lightly run down, they should be torqued to keep the pressure even around the circumference of clutch.



15. On cars that permit you to leave the bellhousing in place, install the new throwout bearing in the throwout arm as shown in this photo.



16. When the bellhousing is all one piece you have to remove everything to get at bearing, so it's wise to replace it too when you R 'n' R clutch.



17. Greasing front of splined shaft makes installation of trans easier. You should also grease the surface that the throwout bearing rides on.

18. Once transmission is back in the car, cinch it down and replace shifter and linkage. Be sure to readjust the clutch linkage, too.

Manual Transmission

If Bill Lear had succeeded in producing a steam engine to replace the smog makers we now use, we might have seen the end of all transmissions as we know them today. But Bill Lear didn't quite make it, and it doesn't look like anybody else will, either. So we are stuck with some kind of a transmission to multiply torque so that we can drive our cars.

Obviously, any vehicle with a typical internal combustion engine will need some kind of power-changing device between engine and rear wheels, simply because contemporary engines cannot operate over the very wide rpm range an automobile requires. To start a 3000-lb. car rolling requires more power than is required to keep it rolling. The gasoline engine develops the least amount of torque at low rpm's; consequently the transmission must multiply what force is available at low engine speeds. In this respect all transmissions are alike, both standard and automatic.

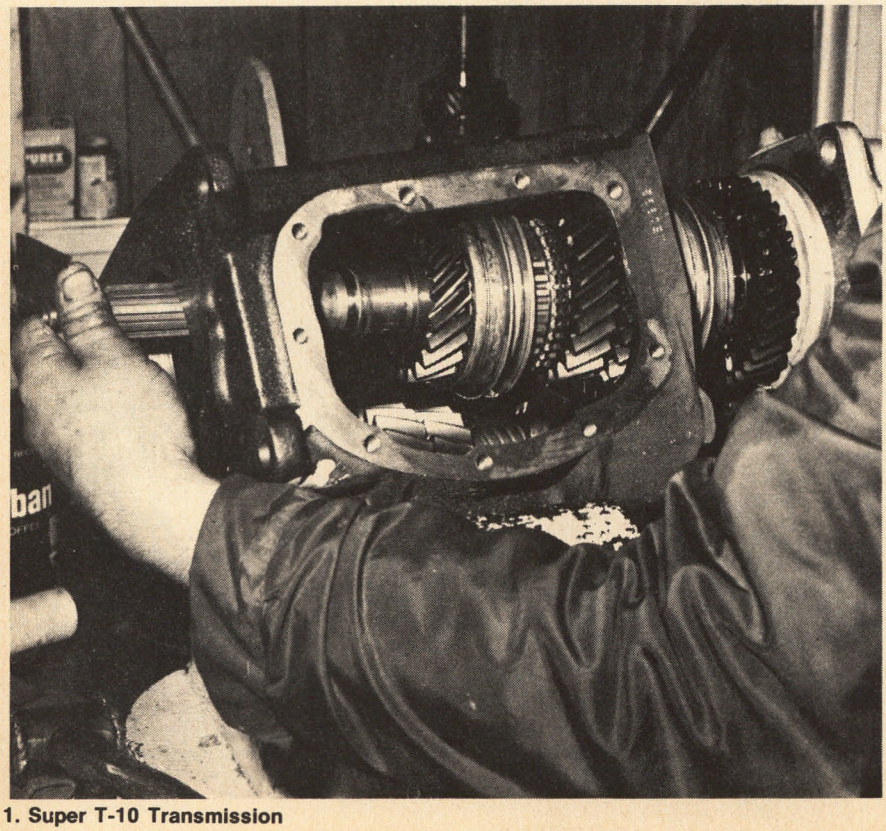
The transmission, then, is nothing more than a mechanical torque multiplier. If you want to move that big rock over there, get a longer lever or move the fulcrum closer to the rock. Now consider the teeth of meshing gears as the fulcrum. The gear with the smaller diameter has the advantage of rotational leverage, and since it will turn faster than the big gear, the engine can run at a higher rpm where greater torque is developed.

Gearing, therefore, of both the transmission and final drive assembly becomes directly responsible for vehicle performance. To this end, the truck may have a very high numerical transmission and rear end combination, the better to move heavy loads. The racing car may have lower numerical gear ratios, since the engine is kept running near maximum power range at all times. To clear up a bit of confusion, low numerical numbers (those numbers closer to 1) are generally referred to as being high gearing. High numerical numbers mean low gear ratios. The lower the gear ratio, therefore, the greater the torque multiplication between crankshaft rpm and driveshaft or axle rpm.

A Frenchman named Levassor is credited with inventing the sliding gear transmission, although gear or rotational torque multiplication has been around for many decades. Until the automobile created such a wide-spread demand for special gearboxes, however, the sliding gear-type multiplier was of little necessity. The changes in the very few years since cars became common are readily apparent—the Model A and a modern Ford are proof of that advancement.

Before any kind of detailed work can be accomplished on a manual transmission, it is advantageous to understand just how the pieces function—at least briefly.

There is nothing secret about how a transmission works, and that's why repairs are so easy to handle. However, before tearing into the gearbox, be advised that there are certain tools which are essential to efficient work. First of all, a good set of expander pliers will undoubtedly be needed to remove the several snap rings. Bearing pullers or graduated diameter punches are essential, and even a dial indicator will come in



1. Super T-10 Transmission

1. Working on a manual transmission like this Super T-10 is really quite easy; all you have to do is remember the sequence in which you took the parts out, and put them back in same order.

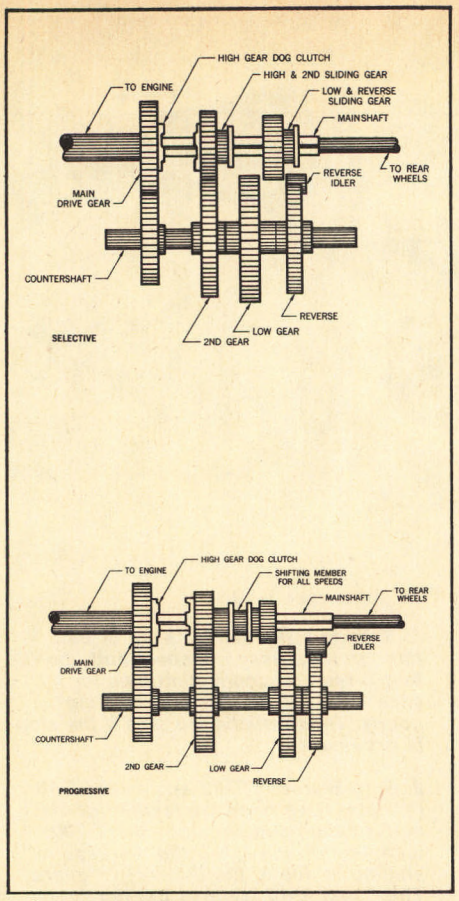
2. Your two basic types of manual transmissions are called selective and progressive. The selective type features neutral in the center or middle of the shift pattern. From neutral, in a selective, you can select any gear you desire. The progressive design, on the other hand, is the type of torque multiplier found on most motorcycles. Neutral is at the bottom of the shift pattern and you must progressively upshift or downshift to reach the particular gear you want.

3. Gear changing on a fully synchronized, constant mesh (including reverse), 3-speed manual transmission is accomplished by shifting forks that have the job of sliding dog clutches over synchros.

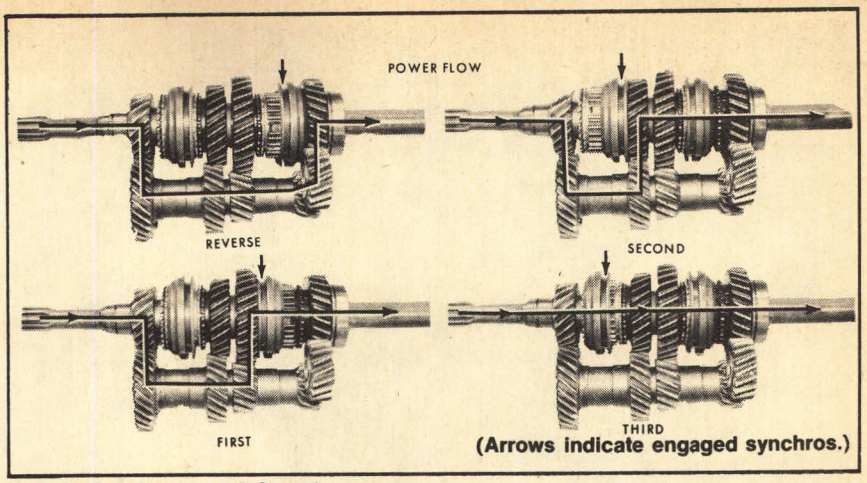
4. GM's medium-duty Saginaw 4-speed trans is used on its intermediate cars, when a 4-speed is ordered with a 6-cylinder engine. All four gears are fully synchronized. The unit can be distinguished from the Muncie by the fact that the reverse lever is mounted on the side cover rather than in the extension housing.

5. Like the manual 3-speed trannys, modern four-on-the-floors feature a constant mesh principle except when reverse is grabbed. Then a special fork on the linkage meshes the free-wheeling reverse gear to the reverse idler gear on countershaft.

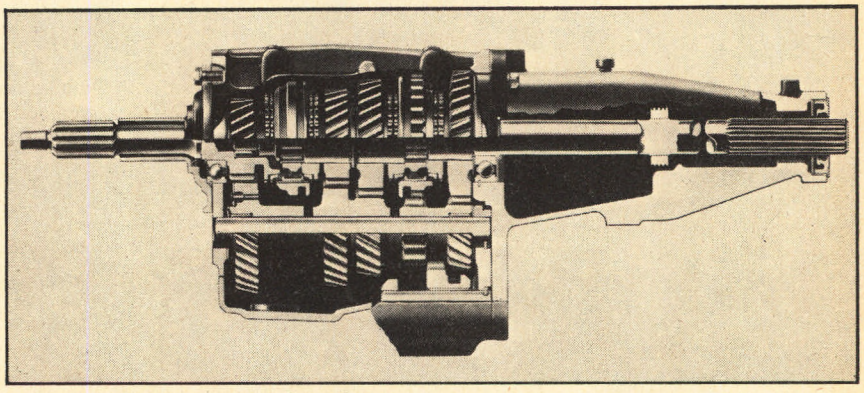
6. Muncie 4-speed transmission is used on most GM high-performance options. The gearbox itself contains the four forward gears, while the tail section houses the reverse gear assembly; trans is quite strong.



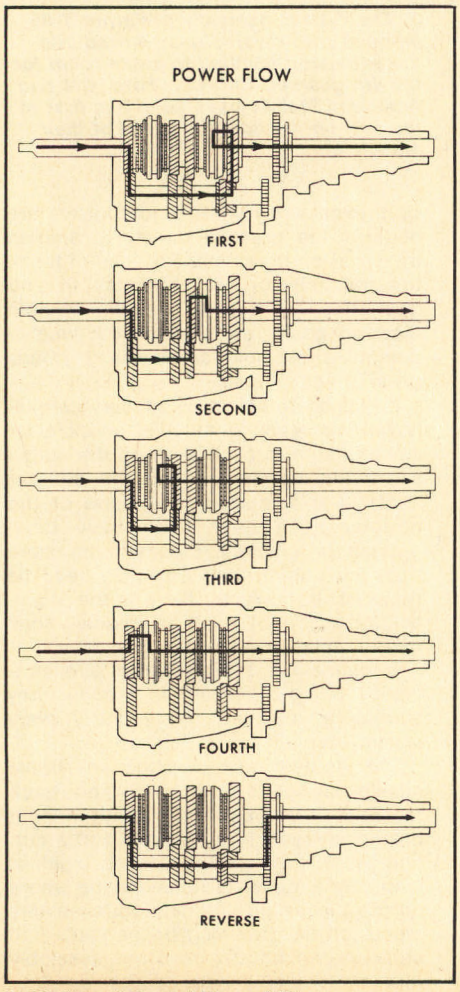
2. Selective and Progressive Transmissions



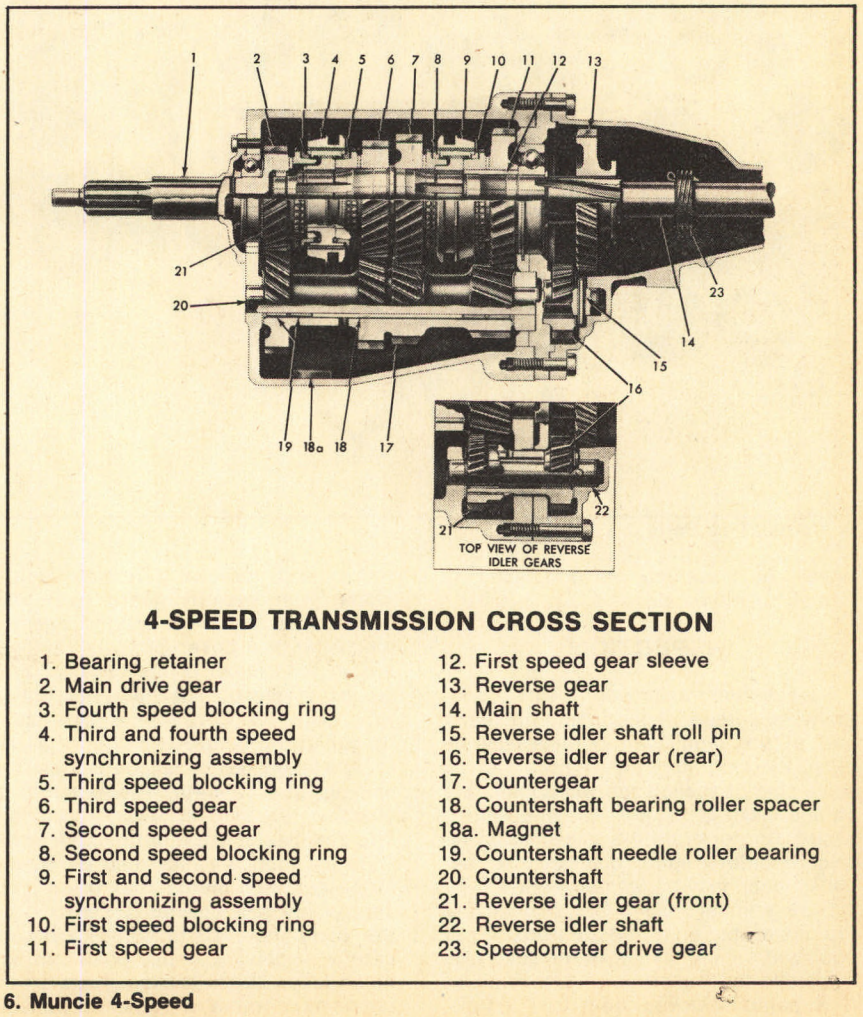
3. Fully Synchronized 3-Speed



4. Saginaw Medium-Duty 4-Speed



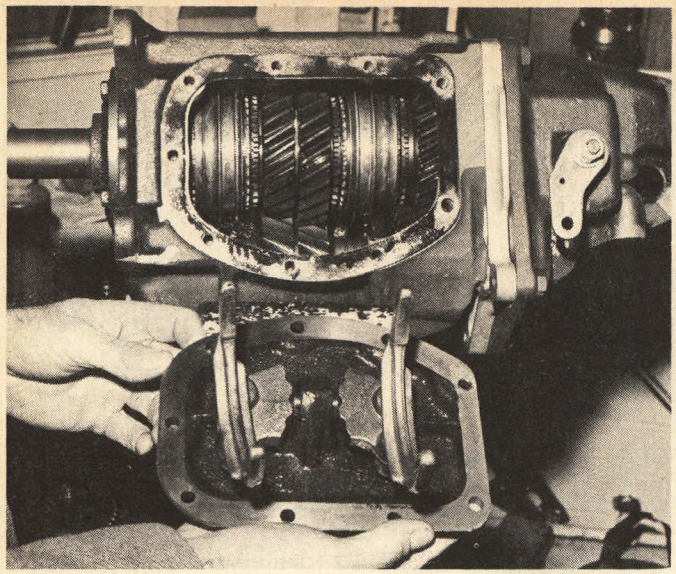
5. Modern 4-Speed Floorshift



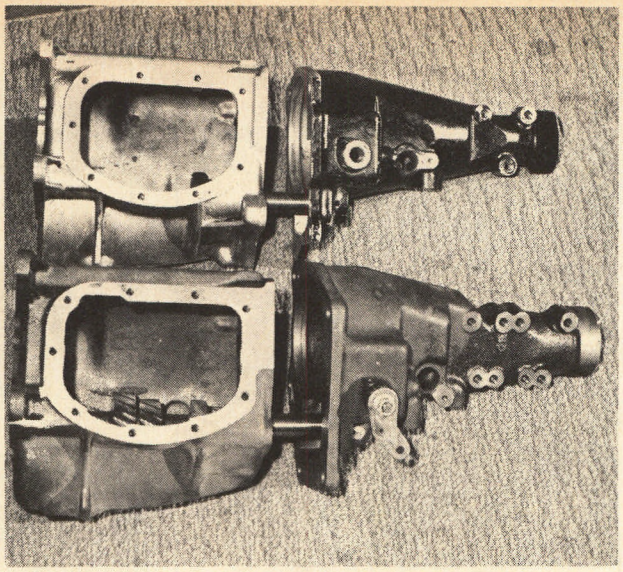
4-SPEED TRANSMISSION CROSS SECTION

1. Bearing retainer
2. Main drive gear
3. Fourth speed blocking ring
4. Third and fourth speed synchronizing assembly
5. Third speed blocking ring
6. Third speed gear
7. Second speed gear
8. Second speed blocking ring
9. First and second speed synchronizing assembly
10. First speed blocking ring
11. First speed gear
12. First speed gear sleeve
13. Reverse gear
14. Main shaft
15. Reverse idler shaft roll pin
16. Reverse idler gear (rear)
17. Countergear
18. Countershaft bearing roller spacer
18a. Magnet
19. Countershaft needle roller bearing
20. Countershaft
21. Reverse idler gear (front)
22. Reverse idler shaft
23. Speedometer drive gear

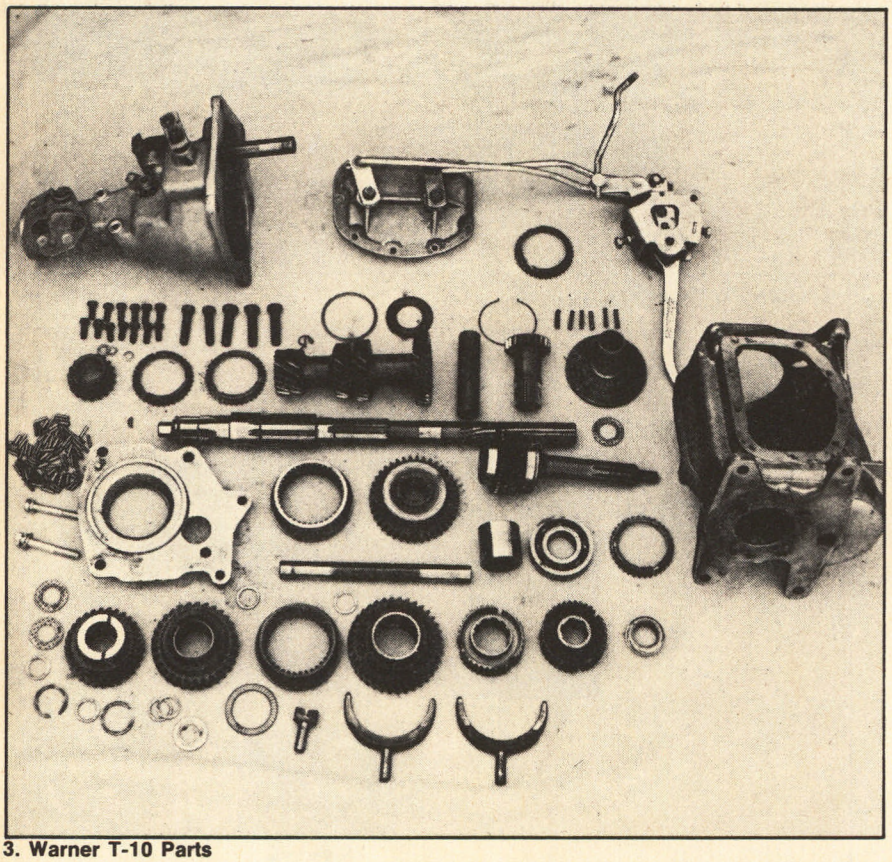
6. Muncie 4-Speed



1. Shifting Forks



2. Comparison of T-10 and Super T-10



3. Warner T-10 Parts

1. Shifting forks can be worn or bent through hard usage. Inspect both the fork faces and connection pins for excess play if your trans is shifting poorly. Then replace the pins if the slop is excessive.

2. Borg-Warner's T-10 and Super T-10 (bottom) have been the favorite of the performance addicts since the T-10's inception on the '57 'Vette. Its ease of shifting is due to the lightweight gears. The Super T-10 features heavier, stronger gears.

3. The T-10 is basically a Warner T-85 3-speed with reverse gear moved into the extension housing to make room for the 4th gearset. Chrysler, Ford, GM and American Motors have used this first of the four-on-the-floors in many of their muscle cars.

handy. All these may be purchased, of course, or rented.

INSPECTION

Because the transmission gears are literally immersed in lubricant, the early part of the repair will of necessity be dirty. Working in a large drip pan or some kind of shallow tub will confine the oil and make subsequent clean-up much easier. Do not drain the transmission lubricant before initial disassembly, because much may be learned from it.

During initial inspection, remove the top cover plate, if the gearbox is so equipped, or the shifting lever cover. Do not jostle the transmission too much as it is being removed from the vehicle, since small particles of metal, such as chips from broken gears, will wash around and become lodged in bearings, etc. After the cover plate is removed, feel in the bottom of the case for these pieces of metal. They are not uncommon, and will give some clue as to transmission failure—whether the gear tooth was broken by fatigue or from hard shifting, and so forth. The synchronizer clutches are sure to wear, resulting in fine particles of brass in the case sump.

All the lubricant may then be dumped in the pan, and the gearbox given a cursory cleaning if desired. Disassembly of the component parts comes next, but careful inspection at this point can save much labor. While broken gears are not uncommon within a standard transmission, excessively worn synchronizers are perhaps the greatest enemy to smooth transmission operation. Because of them, the transmission will not stay in 2nd gear, nor will it shift smoothly without clashing gears, etc. Now is the time to determine just how far disassembly must go to effect a repair.

If gear teeth are involved, very carefully go over each gear. It is possible for several teeth to be broken on the output shaft, but no damage on the counter shaft. If this is true, and none of the counter shaft gear teeth have been gouged or chipped, then nothing more than the output shaft assembly need be repaired. If, however, there is the slightest indication of harm to counter shaft gears, replacement is in order.

Because the synchronizers are constantly being subjected to friction, they should be replaced in practically every repair job.

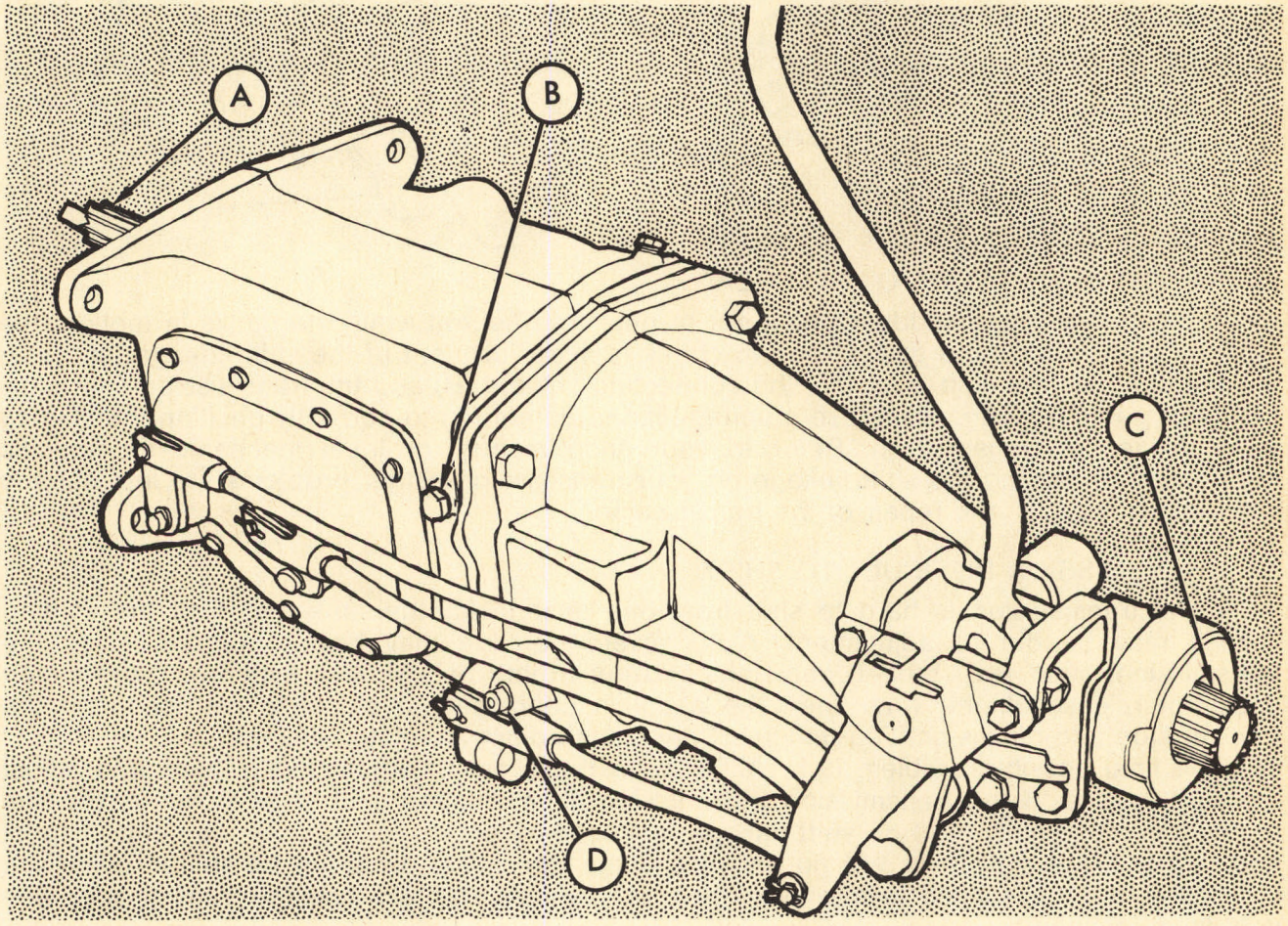
The hardest part of fixing any transmission is getting it apart and back together. If you can get it apart without having to resort to a hacksaw and a cutting torch, then getting it back together is merely a matter of remembering where all the pieces go. To help your memory along, on the following pages you'll find step-by-step photos covering assembly and disassembly procedures on four popular manual transmissions.

TROUBLESHOOTING STANDARD TRANSMISSIONS

TRANSMISSION NOISY WHEN CAR IS IN MOTION

WARNING: BE SURE YOU ARE ON AN OPEN STRETCH OF ROAD WITH NO TRAFFIC WHEN ATTEMPTING TO CHECK FOR TRANSMISSION NOISES. THIS TEST SHOULD NOT BE PERFORMED IN ANY TRAFFIC SITUATION.

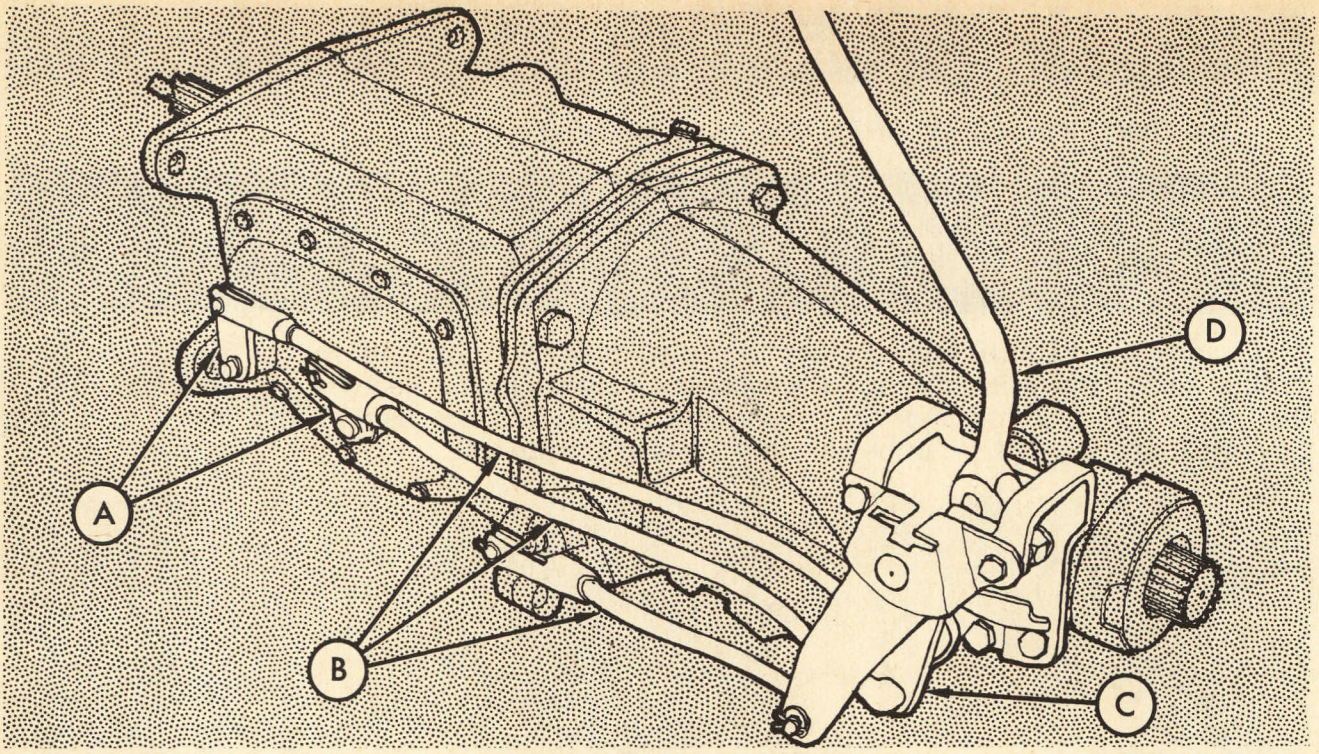
Transmission noises can include whining, clicking or rattling sounds which are often difficult to identify when driving. Transmission noises can be heard much better by turning the engine off and coasting. By moving the shift lever from neutral into the various gear positions, different gears can be selected for testing purposes.



The first item to check if the transmission is making noises is the level of oil in the transmission. Most transmissions have a filler hole on the side (B). Remove the plug and stick your finger into the hole to determine the level of the oil (see your shop manual or owner's manual for specific oil levels). If the level is down, refill the transmission with the manufacturer's recommended oil and retest. Examine the outside of the transmission for evidence of leaks, particularly around the input shaft (C), the output shaft (A) and the speedometer drive (D) on the side of the transmission. Other things that can cause transmission noise are the internal bearings and moving gears, but these are beyond the repair capability of the average car owner. See your shop manual or local mechanic for repair. A noise associated with a particular gear (first, second, third or reverse) indicates a worn or chipped tooth on that cluster gear.

TRANSMISSION NOISY IN NEUTRAL

If the transmission makes noise in neutral with the engine running but when the car is not in motion, check the oil level. Noise may also indicate a worn clutch gear, clutch gear bearing, countershaft drive gear or countershaft drive bearings.



TRANSMISSION SLIPS OUT OF GEAR

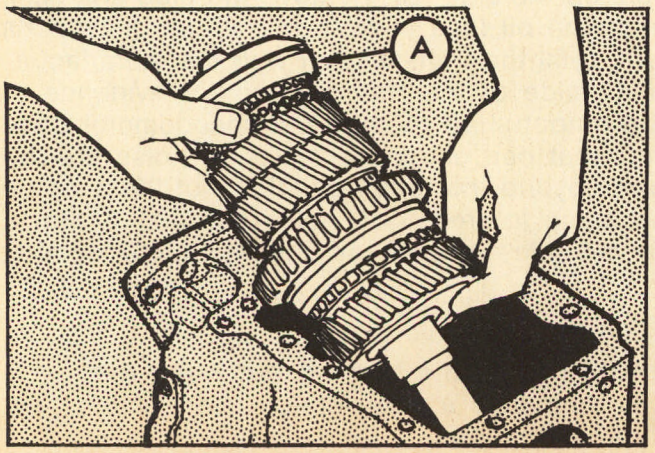
If the transmission suddenly slips out of gear into neutral while the car is in motion, the obvious problem and the easiest one to check is misadjustment of the shift linkage. The shift linkage contains the shift lever (D), the connecting linkage (B) and the transmission shift arms (A). Most shifting mechanisms use a spring-loaded detent (C) to correctly position the shifting forks inside the transmission. Refer to your shop manual or local mechanic for specific information on setting the shift linkage on your transmission. Other problems are internal and will require removal and repair of the transmission.

TRANSMISSION DIFFICULT TO SHIFT

If the transmission is hard to shift from one gear to another, the clutch or the shifting linkage may be out of adjustment. Also, severe damage may have occurred inside the transmission, such as a broken gear, chipped gear tooth or a broken synchro. If the clutch does not release all the way when the pedal is depressed, it places a restriction on the transmission and makes shifting difficult. Check and adjust the clutch linkage.

The final possible problem is a shift linkage that's out of adjustment. Check and adjust the shift linkage. If the transmission will not shift at all but the shift lever moves easily, the problem is most likely that the shift linkage has become disconnected at some point. Inspect and repair. If the shift lever will not move and the transmission cannot be shifted even with considerable force applied to the lever, there is serious damage inside the transmission. See your local mechanic.

GEARS CLASH WHEN SHIFTING



Gear clash or "grinding" can be caused by one of several problems. The most likely is that the synchronizing units (A) are worn. These devices match the rotational speed of different gear clusters so they can mesh smoothly. Worn synchronizers must be replaced. Another possibility is shift linkage misadjustment or slight dragging of the clutch. Dragging of the clutch takes place when the clutch does not completely release when the clutch pedal is depressed. This can be due to faulty linkage adjustment or a worn clutch pressure plate assembly.

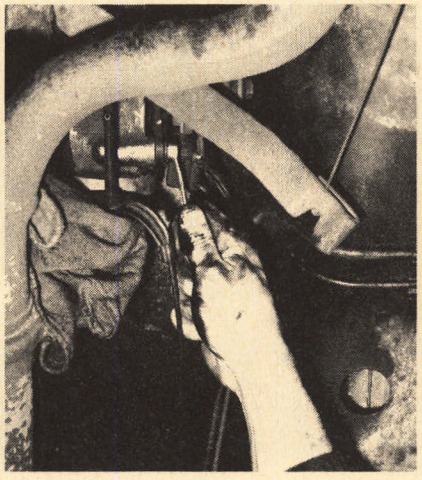
HOW-TO: Removing a Manual Transmission

1. Before you drop your trans, find drain plug and remove oil. Then mark chalk across U-joint's face for reassembly in original position.

2. Four nuts, two U-bolts will free assembly from rear yoke. Inspect U-joint for wear at this time; replace or rebuild it if necessary.

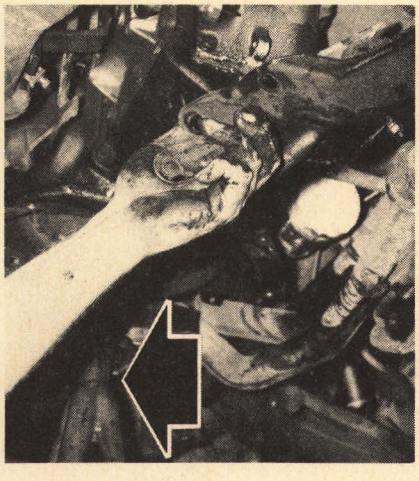
3. Remove exhaust system if it is an obstruction to disengaging of shifter linkage or lifting of trans. Now pull linkage cotter keys.

4. Speedometer cable can be disconnected by taking off Phillips cap screw. If location of pipe hampers work, use shorter tool.

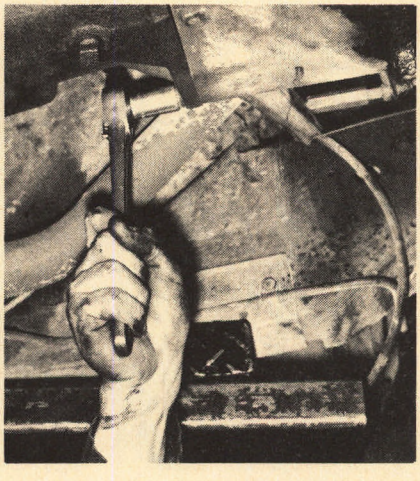


5. Disconnect shift linkage at transmission. If linkage is for a floor shifter, you may be able to lift entire assembly from inside car.

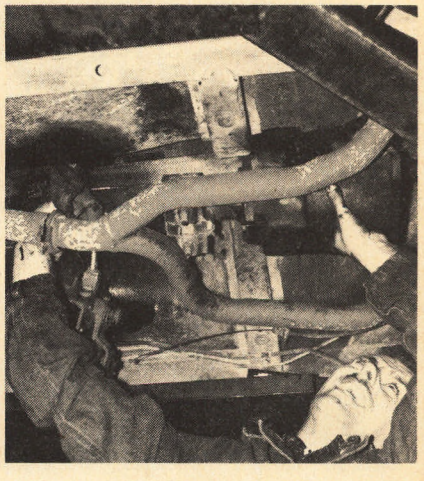
6. Middle crossmember, holding tailshaft, is now unbolted from frame. If handbrake cable is in the way, it too will have to be removed.



7. As arrow indicates, you must support rear of engine when you take off transmission support. If you fail to do so, engine will fall out.

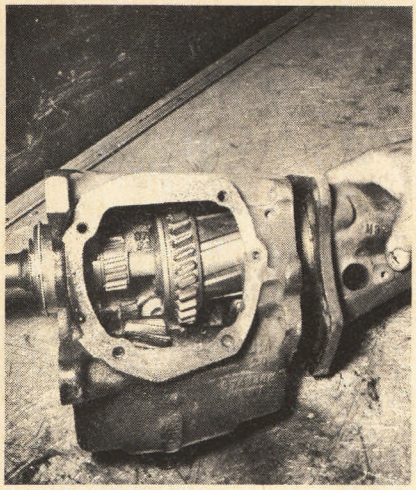


8. You needn't support trans. Main shaft and bearing sleeve on bellhousing will keep gearbox in place as you loosen bolts with a ratchet.

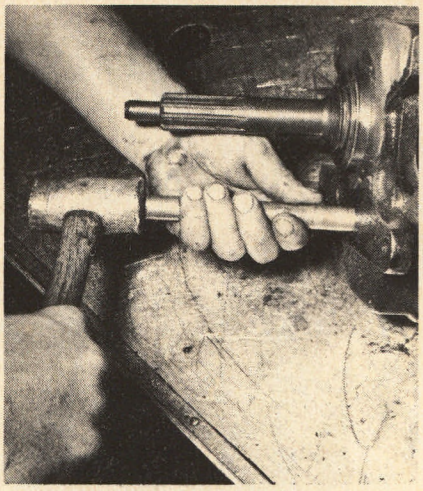


9. "Get all the goodies out of the way!" Exhaust head pipes, linkage and hand brake cables will make a hard job harder if they aren't removed.

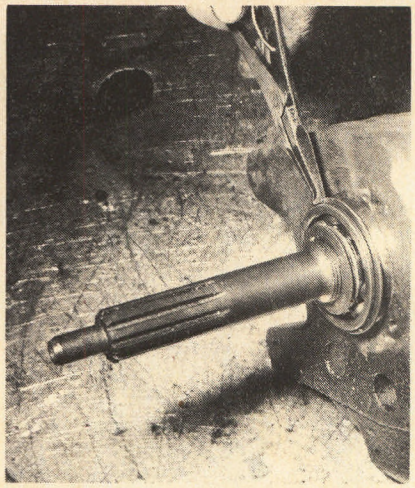
HOW-TO: Disassembling a Chevy 3-Speed



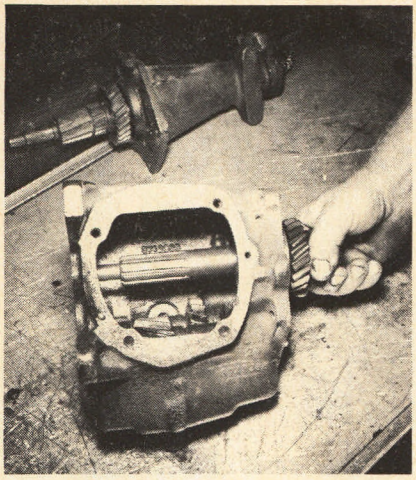
1. Before disassembling/reassembling Chevy's old 3-speed trans, drain lubricant and; remove both side cover assembly, tailshaft housing assembly.



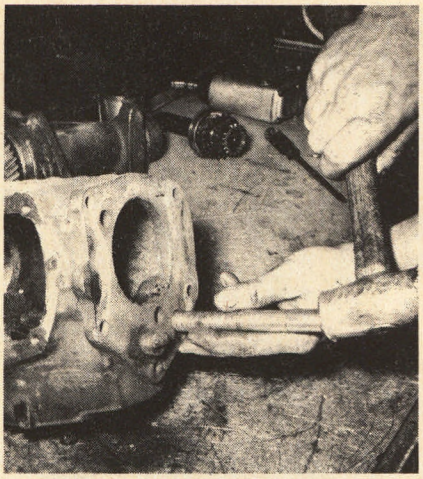
2. Now slide reverse, first gear from clutch sleeve; remove them from case. Remove pilot bearing, retainer screws before tapping out countershaft.



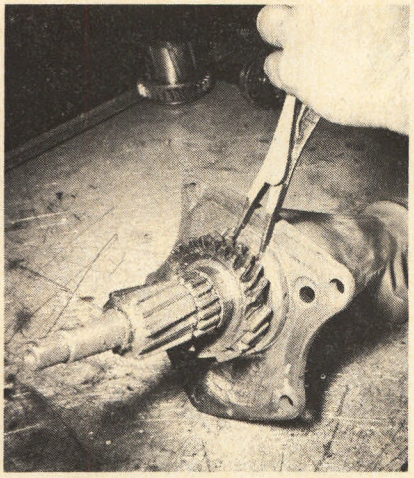
3. Lower countergear to bottom of case before removing clutch gear, bearing. Otherwise bearing will strike countergear. Now pull snap ring.



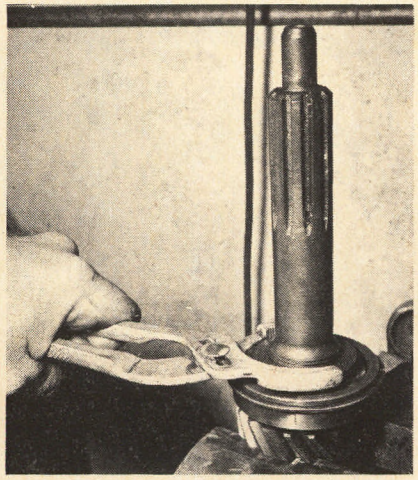
4. Tap end of shaft with a soft mallet to move gear and bearing assembly into front of case. Then total assembly is pulled from rear of case.



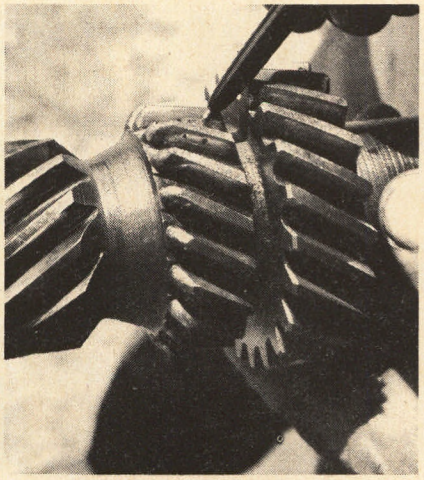
5. Now tap out reverse idler gear, thrust washer, thrust bearing and bearing washer after driving out plug located ahead of idler shaft.



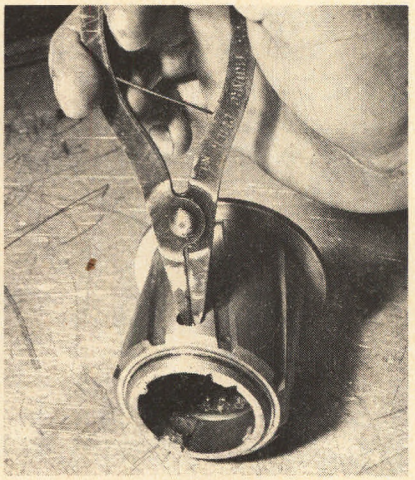
6. To take mainshaft off extension, expand bearing snap ring; tap rear of shaft with a soft hammer to free the shaft, speedo drive, and second gear.



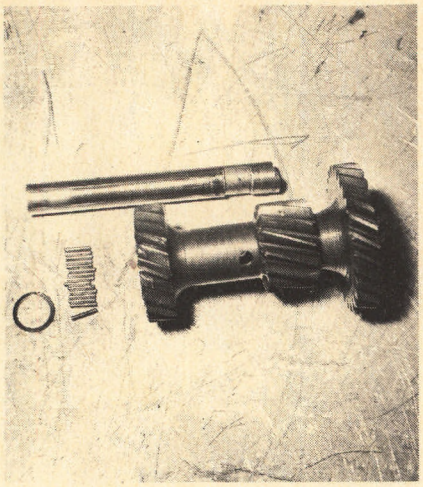
7. Place clutch gear in a vise and remove bearing retainer nut and oil slinger with some water pump pliers. Bearings must be pressed off shaft.



8. Replace gears if they show unusual wear; check first, reverse, be sure they slide easily on clutch sleeve. Do same on clutch sleeve-to-mainshaft bit.

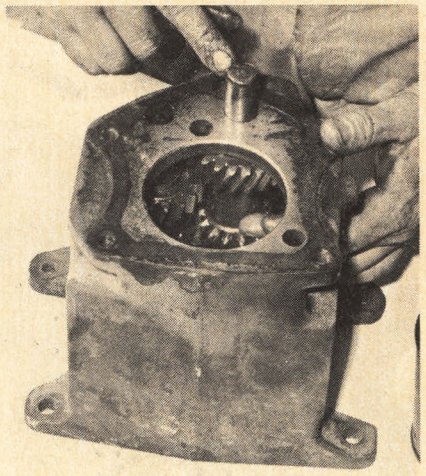


9. To remove synchronizer ring from clutch sleeve, turn ring until its ends can be seen through slot. Slide retainer out of groove with snap rings.

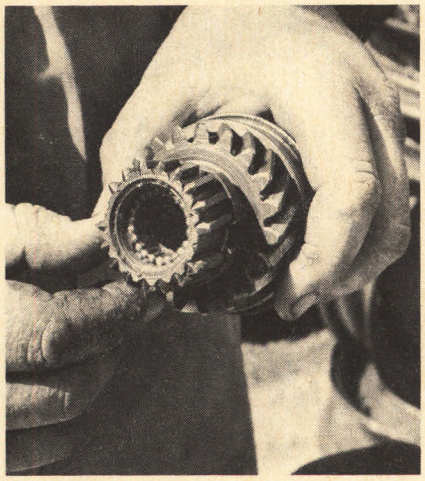


10. Cluster is a prime point of hard wear; its bearings should be renewed. Note number of thrust washers on each end of gear; reassemble with same.

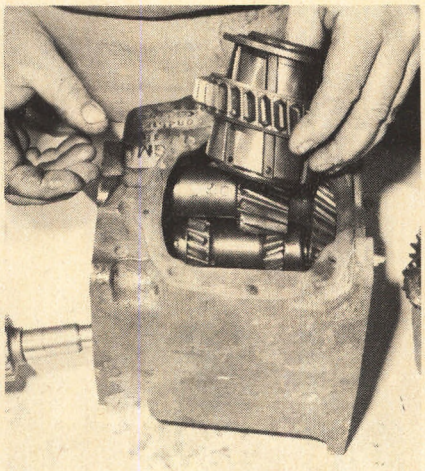
11. Before installing assembly, use heavy grease to hold needle bearings in cluster. Fit gear into case; install cluster countershaft.



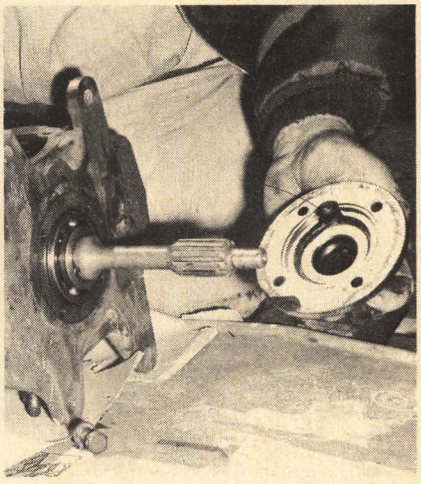
12. Position reverse idler assembly in case so thrust bearing faces rear. Install idler shaft, make sure flat spot is down so extension will fit.



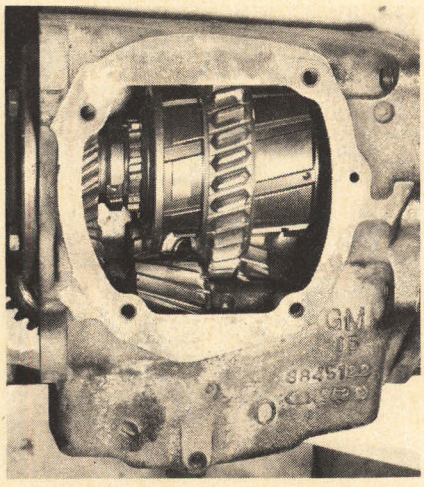
13. Use cup grease to hold mainshaft pilot roller bearings in clutch gear. Make sure no bearing escapes. Insert clutch gear assembly from inside case.



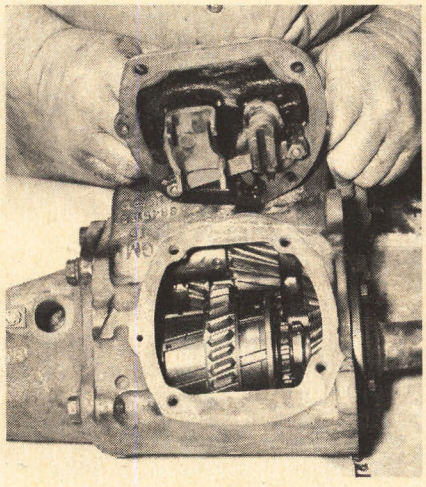
14. Next insert synchronizers, low/reverse slide gear in case. Install rear housing with main shaft to front of case, finish off with main drive gear.



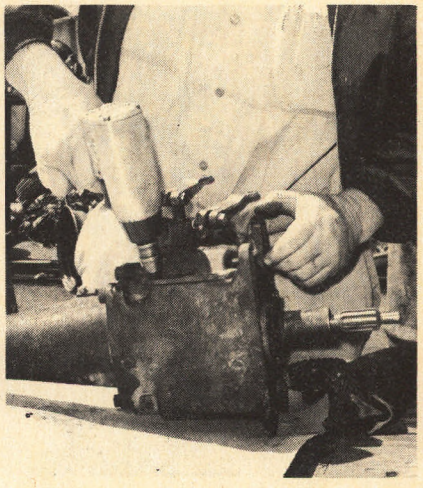
15. Install clutch gear bearing retainer and make sure oil slot in retainer lines up with the oil slot that's in the front face of the transmission.



16. Now slide reverse/low gear into neutral (center) position on 2nd and 3rd-speed clutch before you bolt side cover plate to trans case.

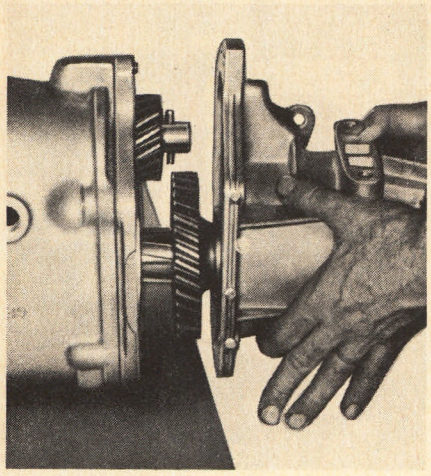


17. Inspect shifter forks for wear (replace if necessary). Preset forks for neutral. Hump on first, reverse must face toward rear of trans.



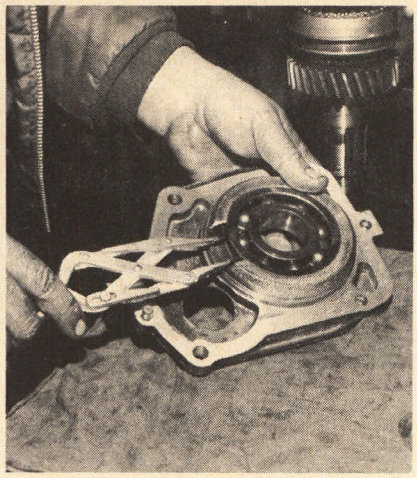
18. Use new gasket; coat the capscrews with Permatex No. 2. Cinch up with torque wrench or impact gun. Recommended torque is 15-18 ft.-lbs.

HOW-TO: Assembling a Muncie 4-Speed

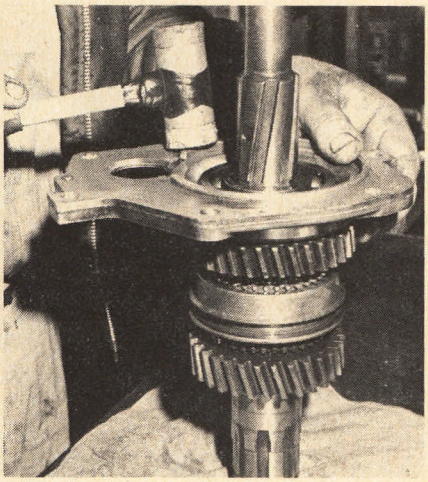


1. Drain lube from trans; remove side cover, clutch retainer housing, rear extension housing, countergear, main drive gear units; clean and inspect.

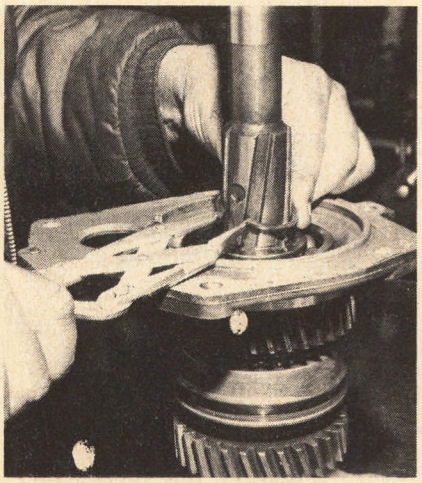
2. Begin assembly by checking bearings for undue wear, then lubricate with light engine oil. Check gears for wear, clutch sleeves for sliding.



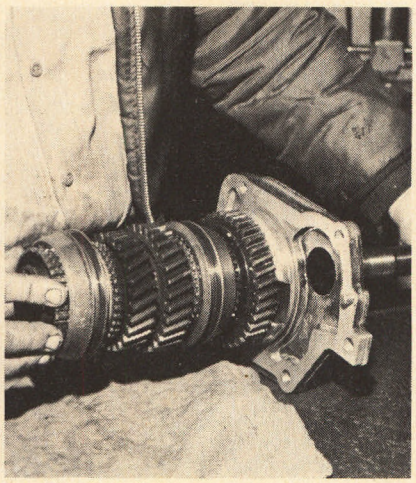
3. After inspecting all moving parts, insert rear bearing in rear bearing retainer; release snap ring, position correctly in retainer groove.



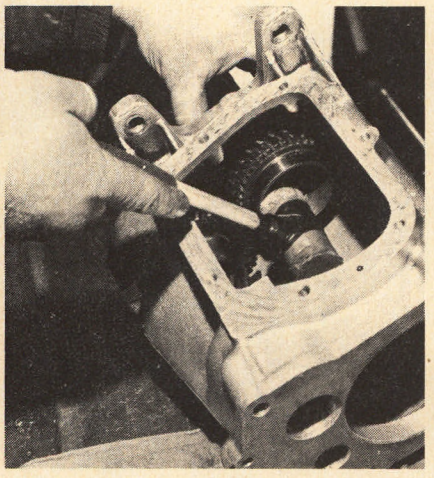
4. Once 1st and 2nd gears (with their synchros, clutch sleeves, etc.) have been installed on mainshaft, tap rear bearing retainer onto shaft.



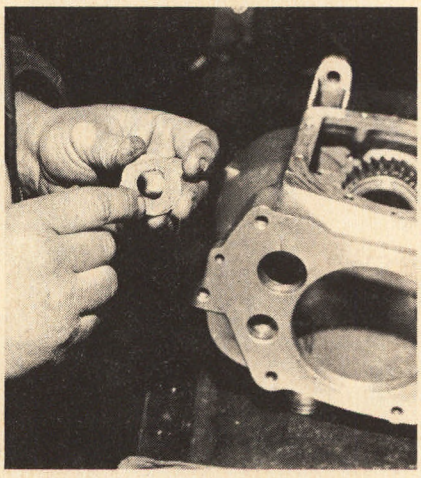
5. Spread snap ring with pliers, then allow ring to align with groove in end of mainshaft to help retain rear bearing. Install reverse, anti-rattle springs.



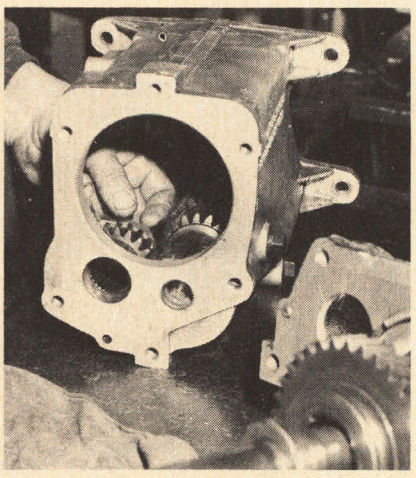
6. Install 3rd and 4th gears (hub to front of trans), synchronizers and 3rd, 4th gear clutch assemblies with both sleeves to front of trans case.



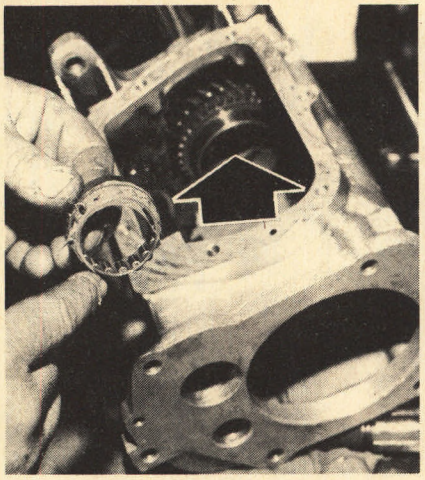
7. Cluster goes in bottom of case with all bearings held in place by dowel. Then tap main drive gear and bearing into hole in case; work from inside.



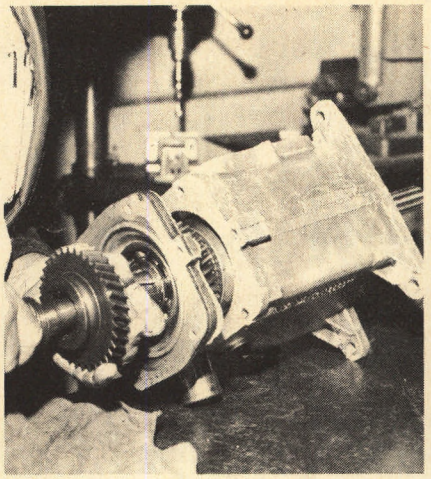
8. Position reverse idler gear thrust washer on machined face of ear cast in case of reverse idler shaft. Hold assembly in case with heavy lube coating.



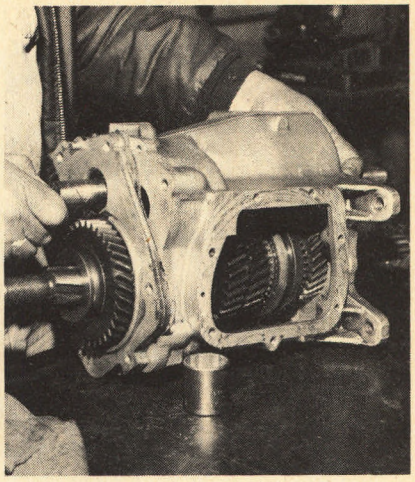
9. Shove reverse idler gear next to thrust washer, with the hub facing to rear of case. Install flat thrust washer on reverse idler gear.



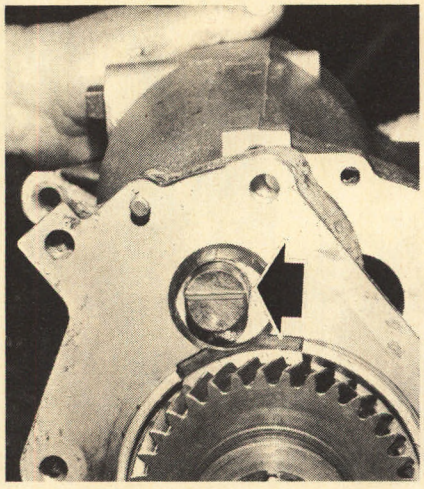
10. Stick cage and its 17 roller bearings into main drive gear; use heavy grease to hold bearings in place. Put oil slinger (concave forward) on gear.



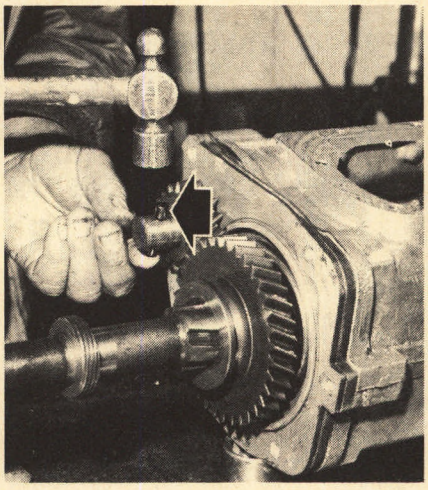
11. Now you can lower mainshaft assembly into case. Be sure notches on 4th gear synchro ring correspond to the keys on the clutch assembly.



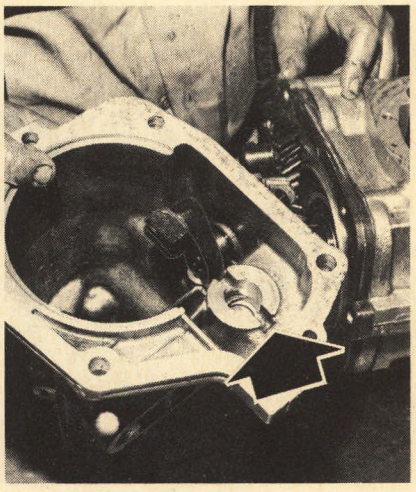
12. Align countergear with shaft in rear and hole in front of case, press countershaft in case, push assembly dowel out until shaft is flush with case.



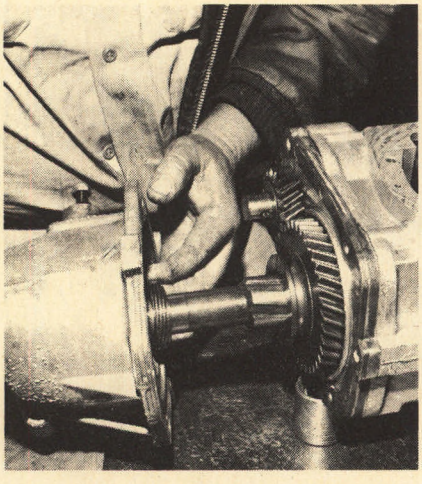
13. Cut on rear of countershaft must be aligned so it will mate to similar cut in rear extension housing to keep shaft from spinning in trans case.



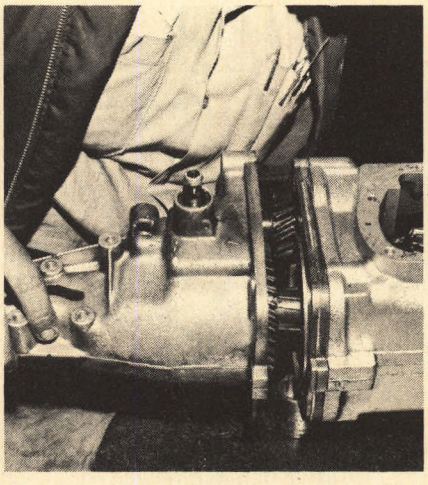
14. Install reverse idler shaft roll pin (pin should be in vertical position), and thrust washer into gear, front boss of case; pick up front-tanged washer.



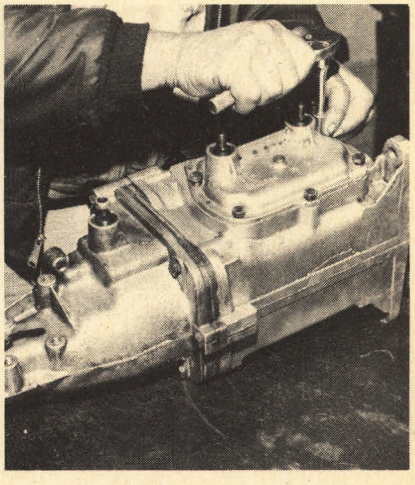
15. Rear extension housing is turned to reveal shifter fork for reverse gear. Arrow shows slot that reverse idler shaft roll pin aligns with.



16. Pull reverse shifter shaft to left side of extension, rotate shaft to bring reverse shift fork into extension housing (reverse detent position).

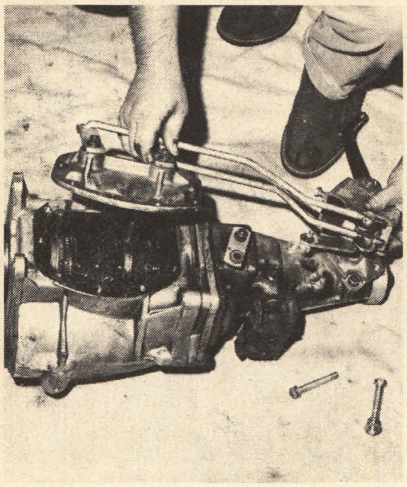


17. Start rear extension housing onto trans case, while slowly pushing it on the shifter shaft to engage the shift fork with the reverse shift collar.



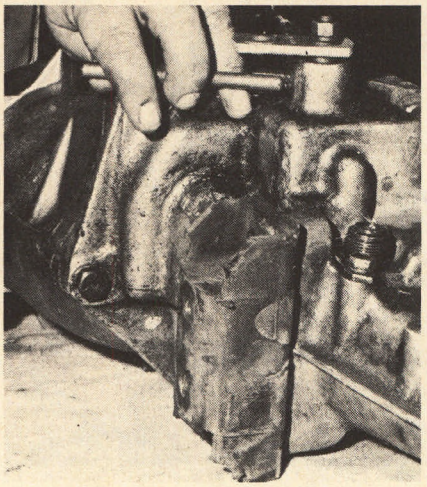
18. Pilot reverse idler shaft into extension; slide onto case, attach bolts. Line up shaft with holes in boss and inset lock pin. Install shifter, side cover.

HOW-TO: Disassembling a Warner T-10

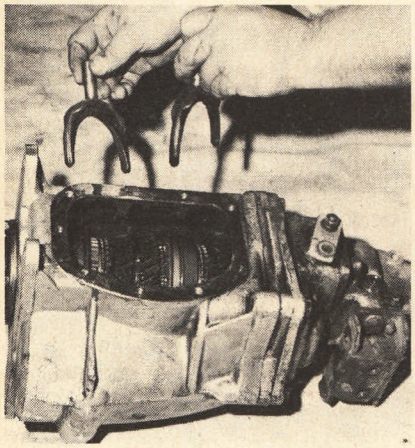


1. Drain out lubricant from Warner T-10 4-speed; shift it into 2nd, remove side cover bolts. Pull cover assembly and gasket off case.

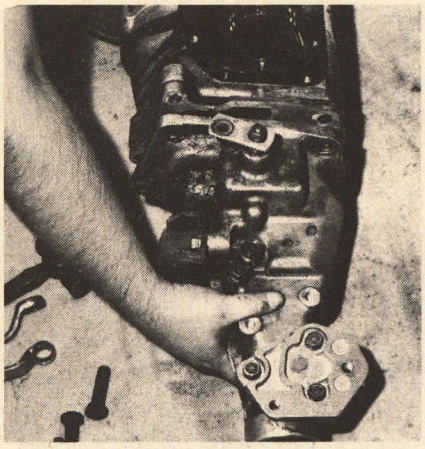
2. Remove front bearing (or clutch gear bearing) retainer bolts from transmission case; slide both retainer and gasket off main drive gear.



3. Take off backup light switch, plunger from trans. Drive lock pin from reverse shifter lever boss, pull shifter out slightly to free fork from reverse.



4. Inspect shifting forks, fork faces, connection pins for abnormal wear or shape. Shifting forks should be replaced to eliminate any excess play.

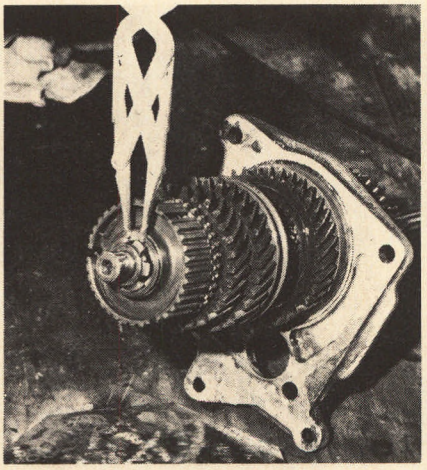


5. Remove rear extension retaining bolts. Tap housing with soft mallet to loosen it. Slide off housing and gasket. Remove reverse idler from case.

6. Shift transmission into 3rd to keep mainshaft from turning. Slide off snap ring from rear splines on mainshaft; remove speedo, reverse gear.

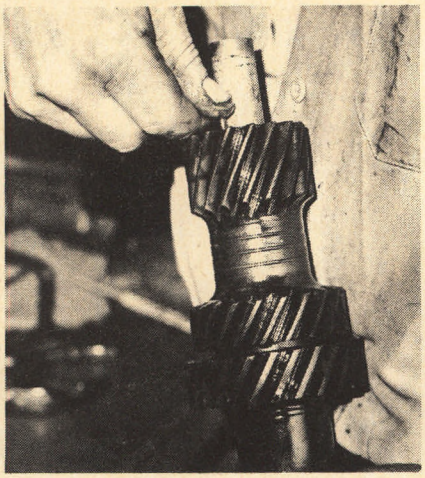
7. Free self-locking bolt attaching rear bearing retainer to trans case. Remove case-to-retainer pin with channel locks or vise grips.

8. Pull clutch gear snap ring so entire assembly can be removed. You may find it necessary to lightly tap shaft and bearing with a soft-headed mallet.

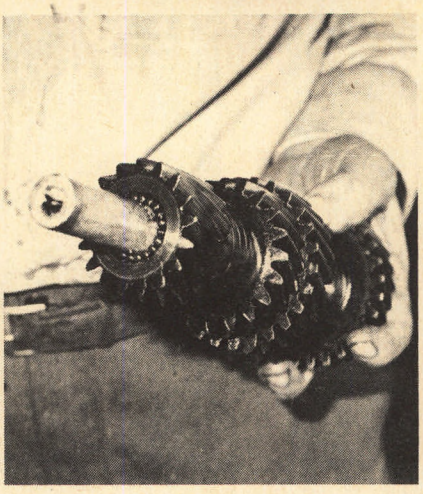


9. To further inspect mainshaft assembly for wear, remove front snap ring, then slide 3rd, 4th clutch assemblies, synchro rings from shaft.

HOW-TO: Assembling a Warner T-10

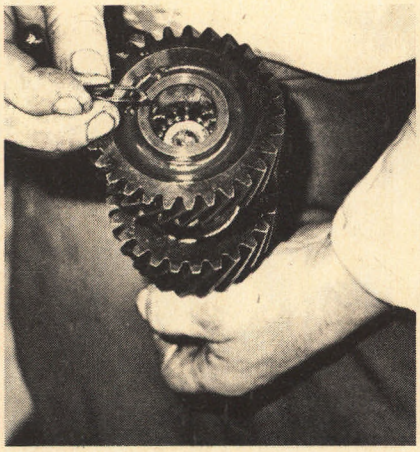


1. Before reassembling bearings and spacers in countergear, inspect teeth closely for excessive wear, chips or cracks; replace it if worn, damaged.



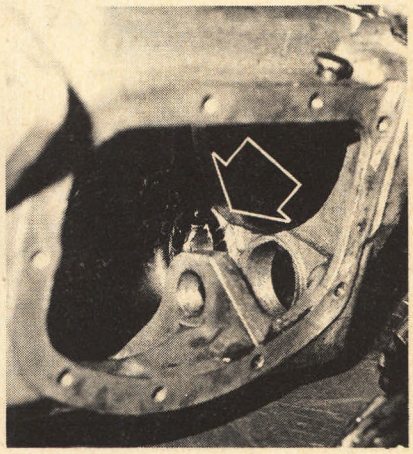
2. While you're at it, check spacers, countergear roller bearings for wear. Inspect countershaft, reverse idler; replace them if necessary.

3. Use a dowel pin or shaft to retain bearings, spacers; slip solvent-cleaned bearings and washers into countergear. Dip in lube so they'll stay in place.

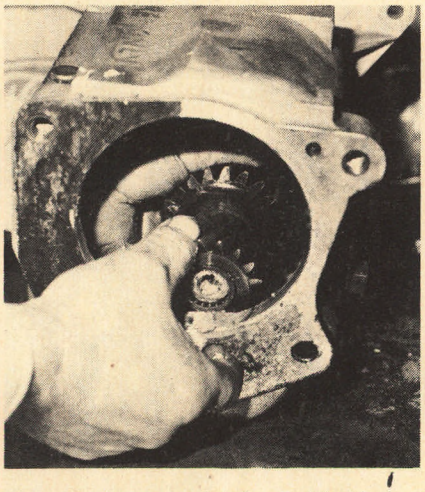


4. The 40 rollers inside countergear are in 4 rows of 10 each, separated by two narrow spaces, one long spacer. Pin is removed as rollers go in.

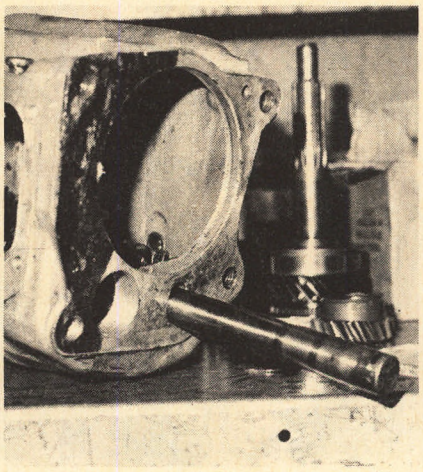
5. Liberal application of lube on cluster gear thrust washers helps hold them in place when countergear is inserted into transmission case.



6. Rest transmission on its side, with side cover opening toward assembler. Put countergear thrust washer in place; hold with a coat of heavy grease.



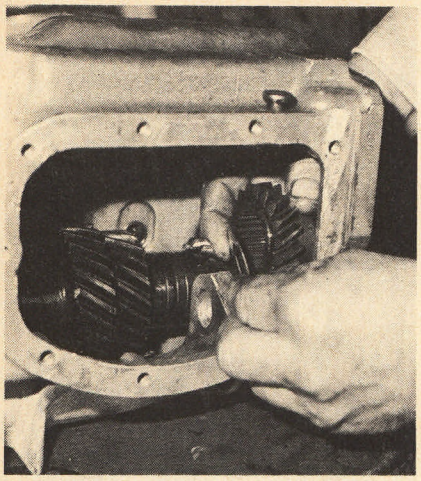
7. Set countergear in place at bottom of case; be sure the tanged thrust washers have not been moved or dowel pin has not slipped away from rollers.



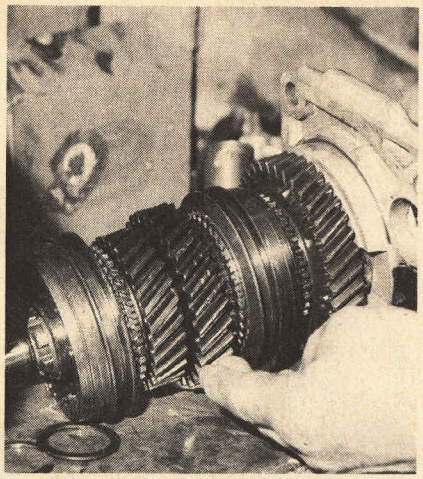
8. Shaft must be removed or it will interfere with assembly of mainshaft and clutch gear. Leave thrust washer in place, countergear at case bottom.

9. Reinstall the 14 roller bearings inside main drive gear; use heavy-duty grease to hold bearings in position while assembly is inserted.

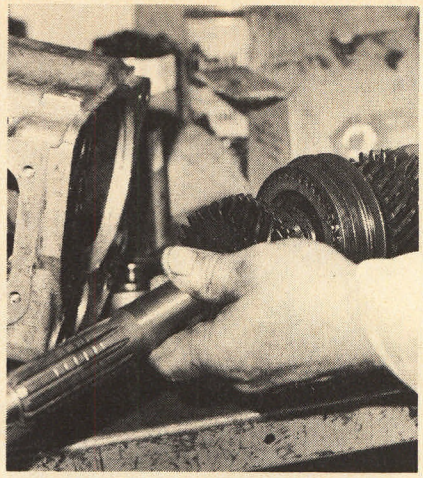
HOW-TO: Assembling a Warner T-10



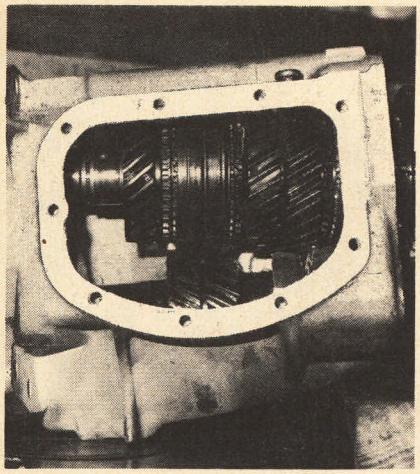
10. When assembling the front reverse idler gear, make sure the teeth are pointed forward with hub facing to rear of the transmission case.



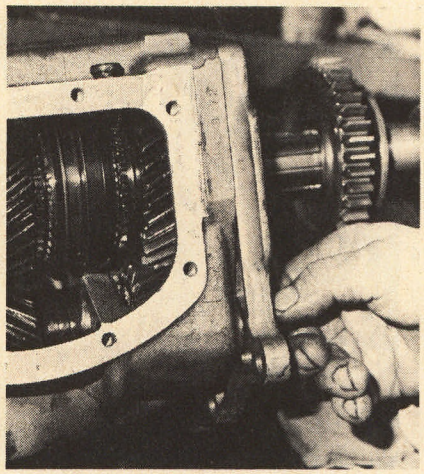
11. The 1st, 2nd and 3rd gears, with synchro rings, are assembled on mainshaft. Hub of 3rd, notches on synchro ring should always face forward.



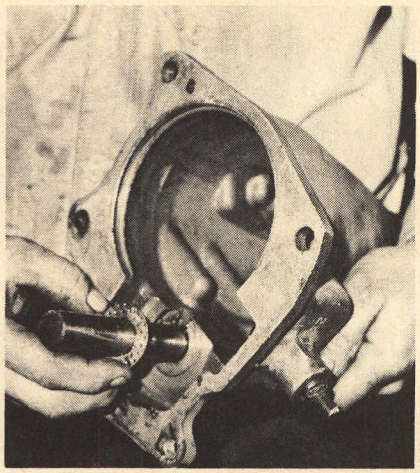
12. Install 3rd, 4th gear clutch assembly with taper to front. Be sure keys in hub match notches in 3rd gear synchro ring. Insert main drive gear.



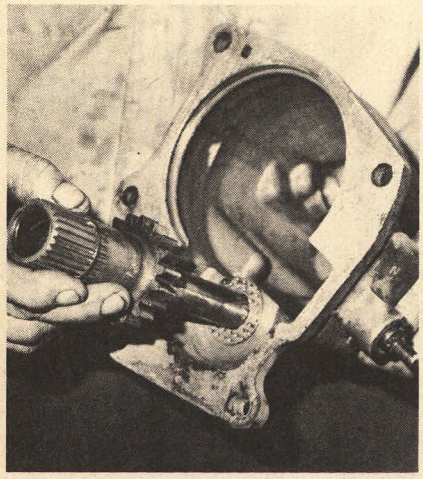
13. Before assembly is put in case, put new selective snap rings (that'll fit in groove) on mainshaft in front of 3rd-, 4th-speed gear clutch unit.



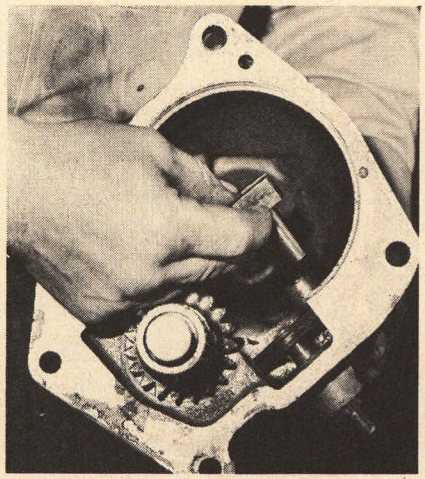
14. Rear bearing retainer can be slid over end of mainshaft. Spread snap ring in pliers so it will drop around rear bearing when aligned with groove.



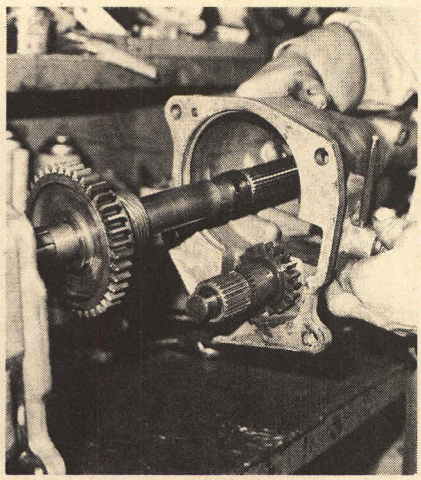
15. First insert reverse idler shaft into housing, then slide flat thrust washer in place. Tang on thrust washer should face thrust portion of case.



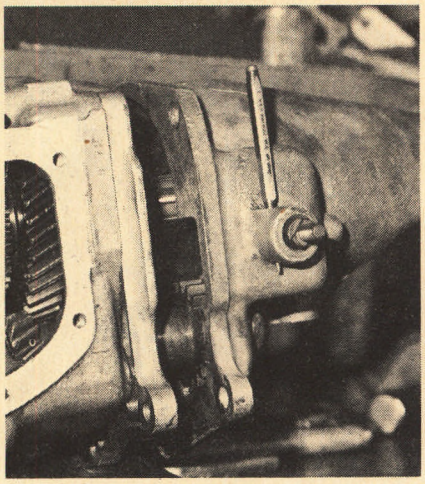
16. Next slip reverse idler gear onto shaft, engaging splines with portion of gear within case. Place new gasket on rear bearing retainer's face.



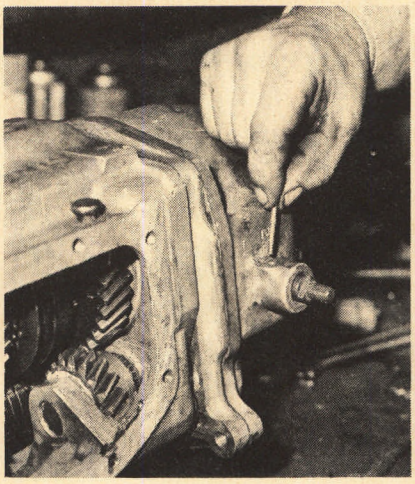
17. Pull reverse shift shaft partially out of extension; rotate shaft to get reverse shift fork as far forward in rear extension housing as possible.



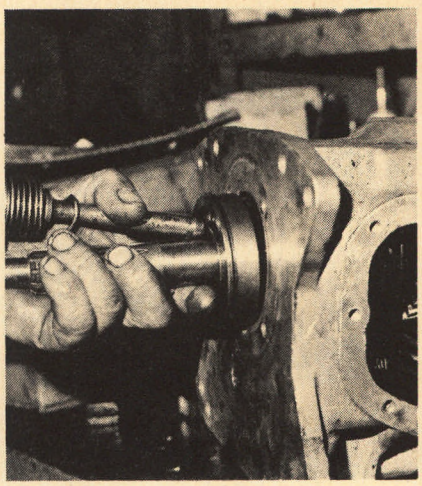
18. Now, you can start the extension onto the mainshaft while pushing in on shifter shaft to engage shift fork with reverse gear shift collar.



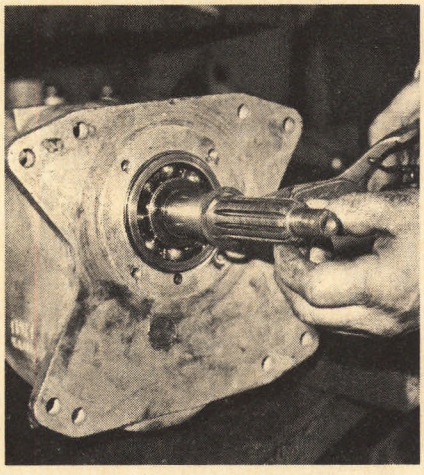
19. When fork engages shift fork, rotate shifter shaft to move reverse gear rearward, permitting extension to mate to transmission case.



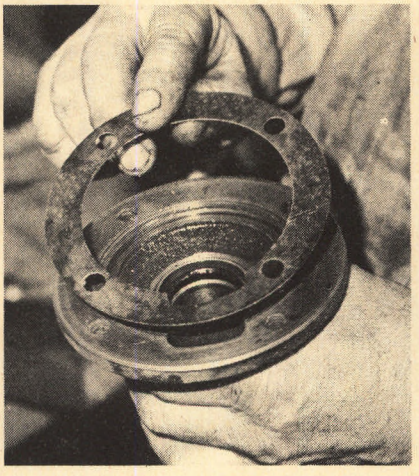
20. With pin in shifter lever boss, torque rear extension housing bolts to 40 ft.-lbs.; install rear extension-to-bearing retainer bolts, 25 ft.-lbs. maximum.



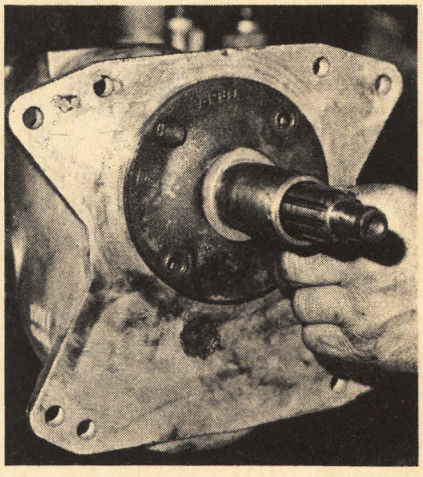
21. With hammer and punch, tap clutch bearing in place. Be sure bearing is clean, lubricated, checked for roughness (by turning race in hand).



22. Use snap ring pliers to slide selective fit snap rings, spacer washer, bearing snap ring over maindrive gear and into proper places.

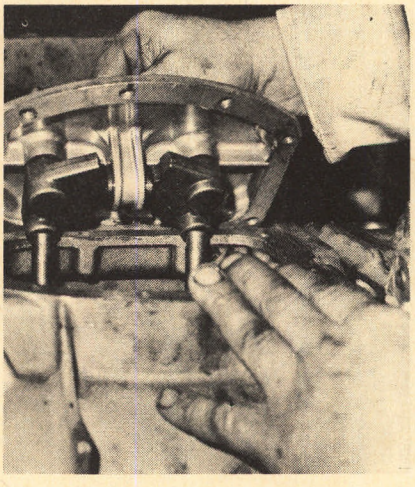


23. Be sure to use a new gasket that's slightly moist with lube, before you bolt bearing retainer to front of T-10 transmission case.

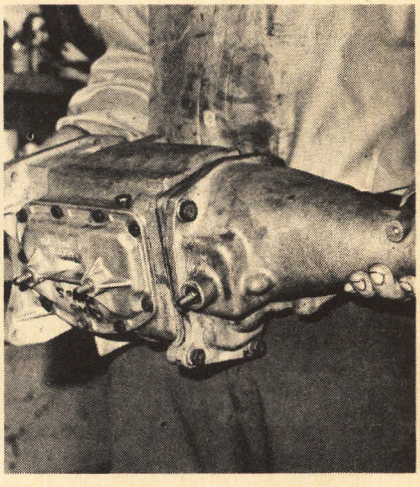


24. New front bearing retainer gasket should be firmly in place and the retainer snug on case. Use good sealer, torque capscrews to 18 ft.-lbs.

25. Shift forks must fit snugly in grooves on 3rd, 4th-speed clutch sliding sleeve and 1st and 2nd-speed clutch sliding sleeve, as shown.

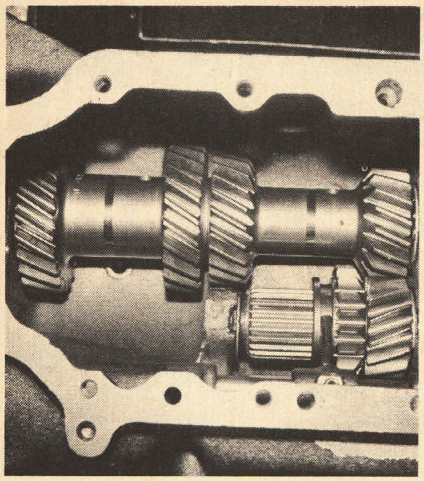


26. Shift trans into 2nd, position side cover, attach new gasket, engage shift forks in collars; install side cover, seal and torque capscrews.

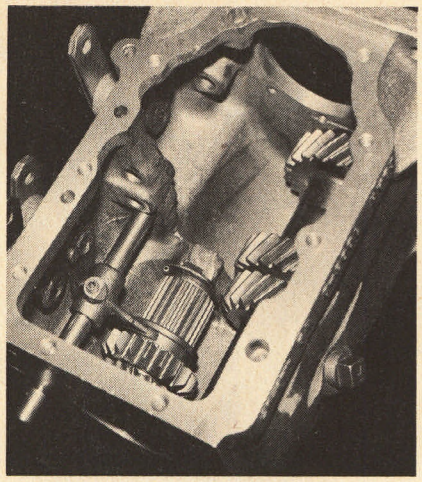


27. After trans is filled and shifter linkage is attached, your just-like-new Warner T-10 transmission is all ready to tackle the streets again.

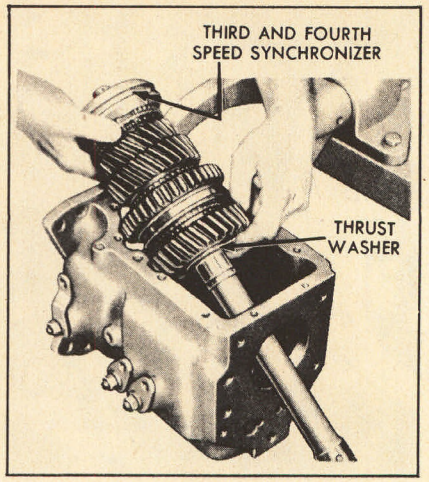
HOW-TO: Assembling a Ford 4-Speed



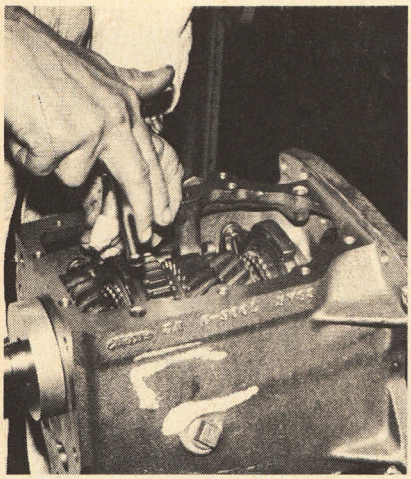
1. Assembly is started by putting the cluster and reverse goodies in position, but the cluster is lying on the bottom of the case without any shaft.



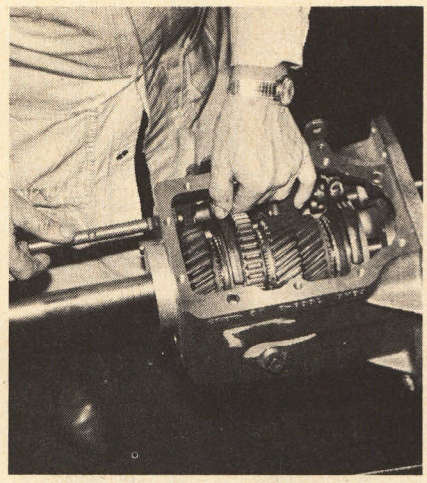
2. The reverse shifter shaft is now in and secured. A set screw holds the shifter fork to the rail. Note the holes for two more shifter shafts.



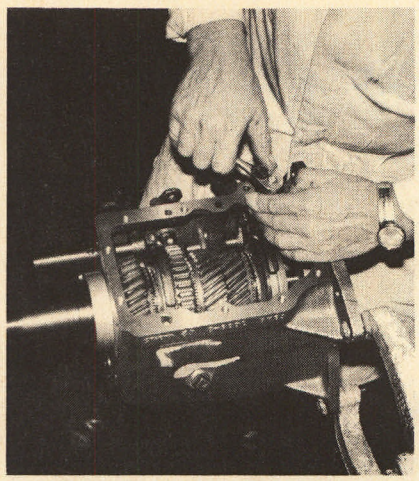
3. Support thrust washer and low gear to prevent them from sliding off end of shaft; then carefully lower output shaft assembly into case.



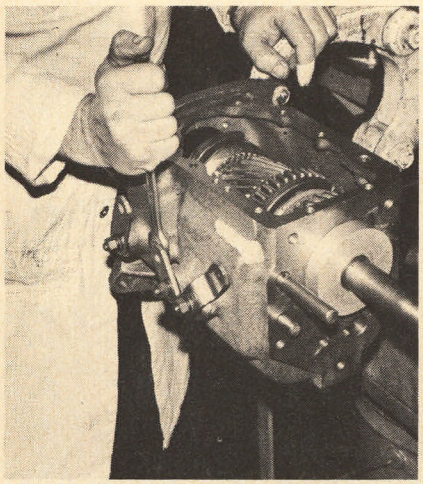
4. Place front synchronizer into 3rd gear position; install set screw in 3rd and 4th gear shift fork. Move synchronizer to neutral.



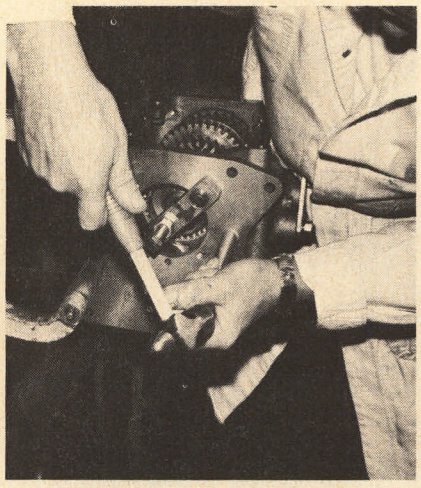
5. The mainshaft, with all the gears already on it, goes in through the top of the case. Then the shift forks and the shafts are put into their positions.



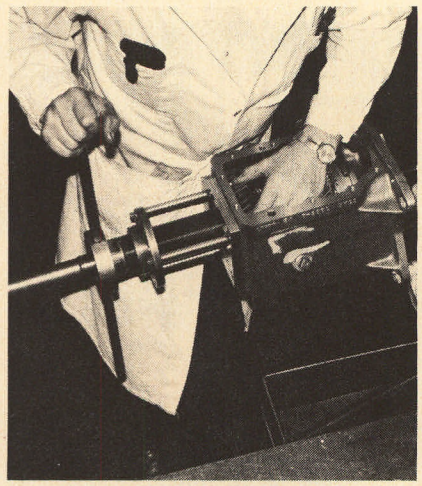
6. Tightening the set screw in the shift fork that helps secure it to the rail. All of the steps are described in detail in genuine Ford shop manual.



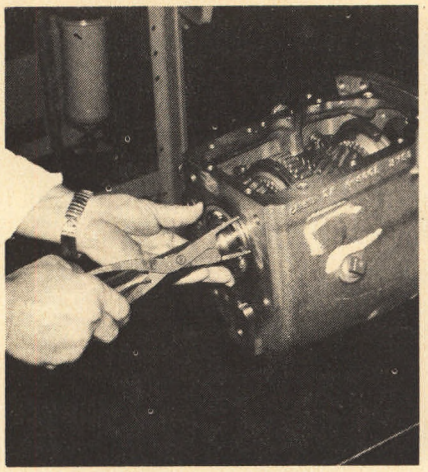
7. The detent on the bottom shift rail screws in from the side of the case. Note dummy aluminum bearing temporarily holding mainshaft in position.



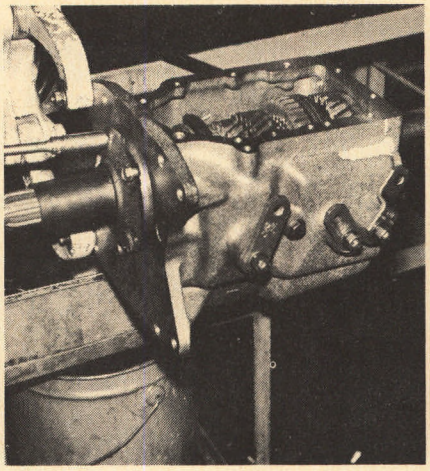
8. Another shift rail is tapped in from the front. Bar across the front of the trans holds the front of mainshaft in position while doing the good work.



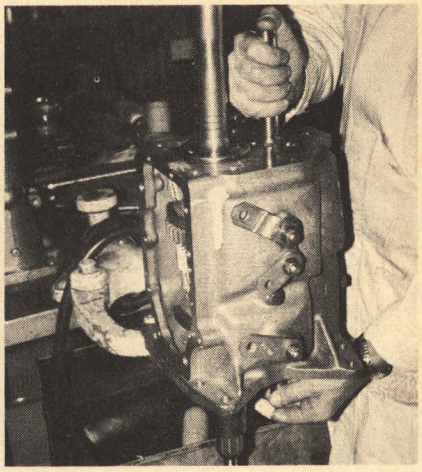
9. Not many people have this press, but it's the right way to put the rear bearing into the case—with no beating. Hammer mechanics, please take note.



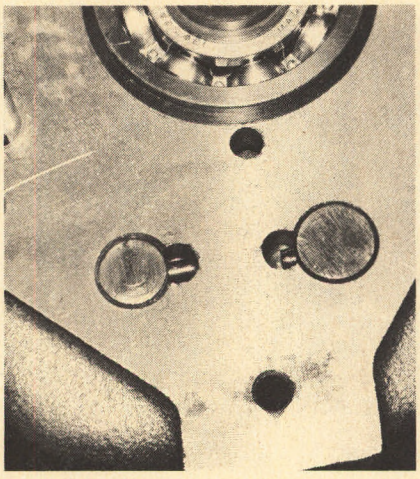
10. After the bearing is in position, the snap ring slips on easily—if you have snap ring pliers. Another snap ring goes on the shaft against bearing.



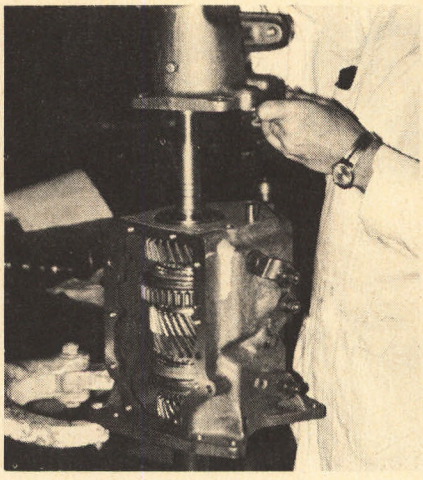
11. After the main drive gear and its bearings are slipped into position, the front bearing retainer, with a new seal inside, is bolted on the case.



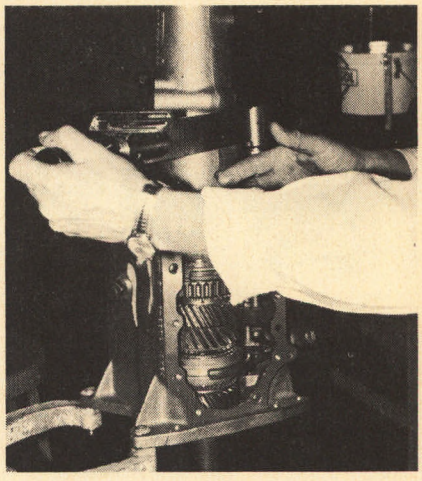
12. Standing the box on end makes it easier to move the gear cluster into position so the shaft can be inserted. Lower hand is catching dummy shaft.



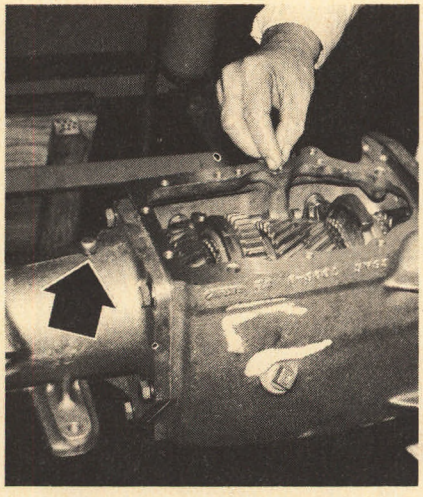
13. The cluster gear shaft and reverse idler shaft are kept from turning by roll pins that must enter these recesses in the case to be held securely.



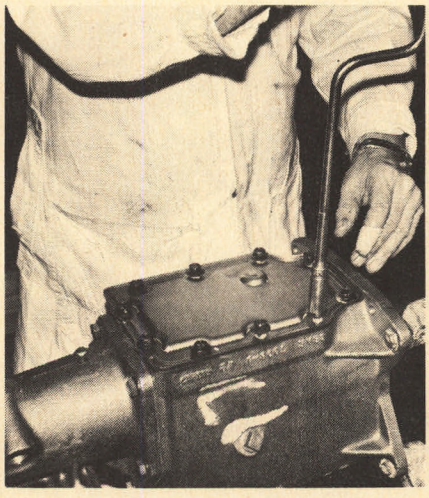
14. First a gasket, and then the tailshaft housing is slid into position. A new seal should be installed in the end of the housing, to stop the drip.



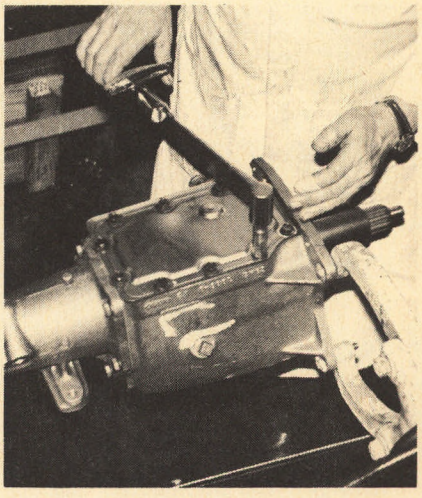
15. Extension housing bolts should be torqued to specs, but you'll not see many mechanics who do it. Tightening by feel might turn out inaccurate.



16. Detent for the top shift rail is dropped into the hole, and held in place by the cover. Note breather on top of housing, to relieve pressure.

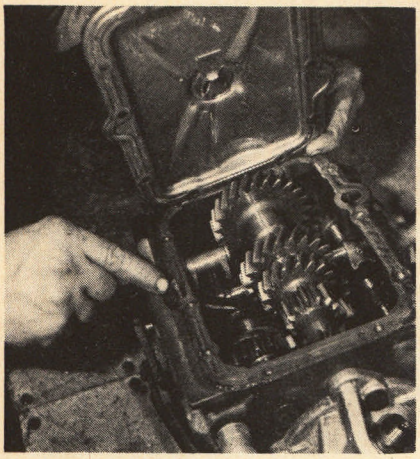


17. The bolts are well greased so that the torque readings will be consistent, but no sealer is used on the cover gasket. Fluid leaks are not a problem.



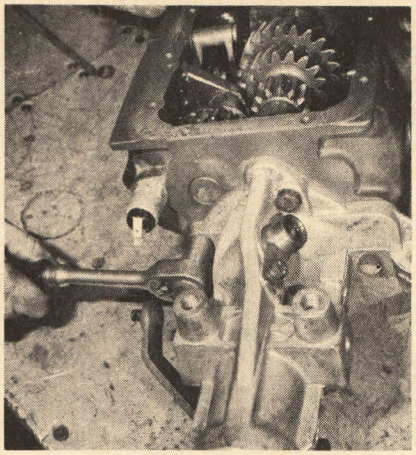
18. That's right, even the cover is torqued. If you're going to be superaccurate, why not go all the way? Reminder: Don't forget to put in lube.

HOW-TO: Vega (Opel) 4-speed Overhaul

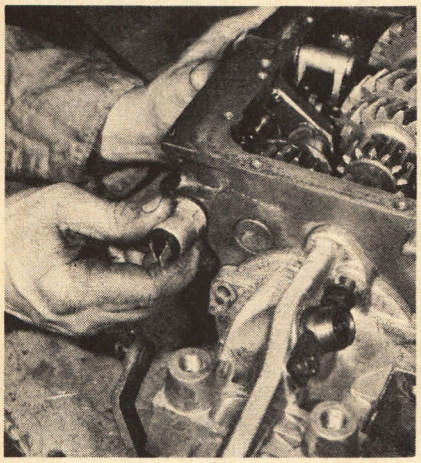


1. The '71-'72 Vega (Opel) 4-speed box is a "bottom-loader:" the case cover is at the bottom of the trans instead of side or top. Watch detent plug and spring when pulling cover.

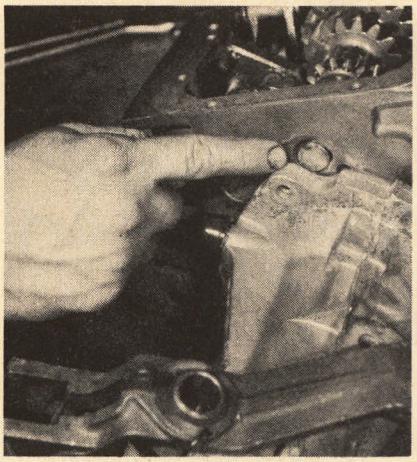
2. Lock nuts, cotter pins and C-clips hold selector lever and shifter shaft arrangement in place and must be removed as a first step before access to trans is possible.



3. Unbolt the extension housing from the trans case. Trans is a German design and requires a good deal of patience during disassembly as working space inside is limited.

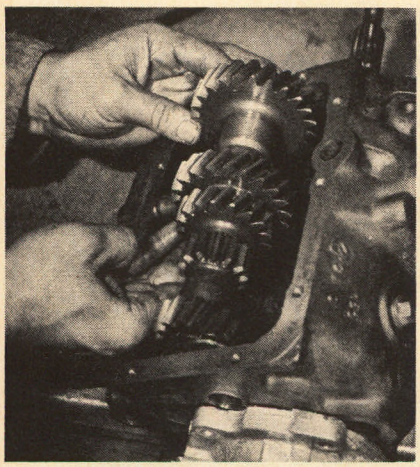


4. Loosen and unscrew the backup light switch from the trans case. "Bottom-loader" design makes countergear removal the next step in the disassembly procedure.

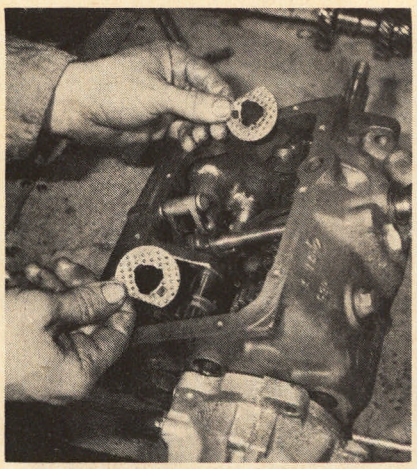


5. In order to provide easy access to the countergear shaft for removal, the extension housing must be rotated until its shaft end completely clears this cutout in the housing.

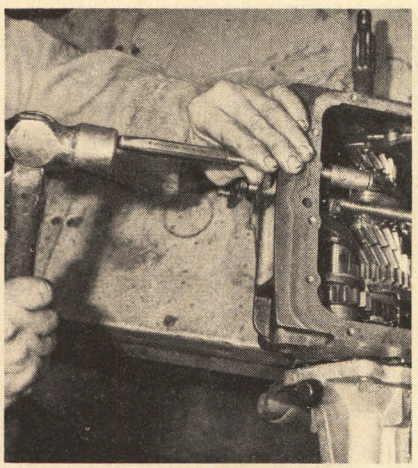
6. Countershaft is removed by driving to the rear with a punch and hammer from the front of the trans case. Watch for a lock ball in rear of countershaft and don't lose it.



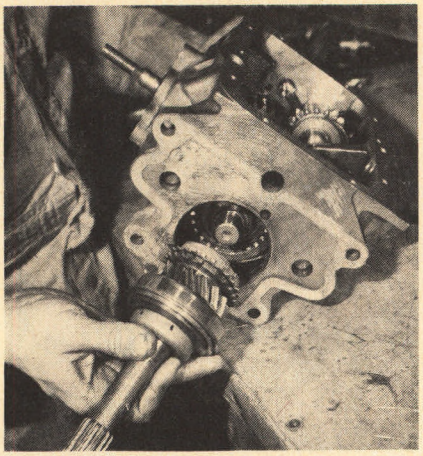
7. Countergear can be lifted out easily with all needle bearings intact once the shaft is removed. Be sure and remember to clean and inspect all gear teeth for damage or wear.



8. The countergear thrust washers are removed next. Note the position of the cut edge, as well as the tangs which must fit into the recesses provided in the case when replaced.

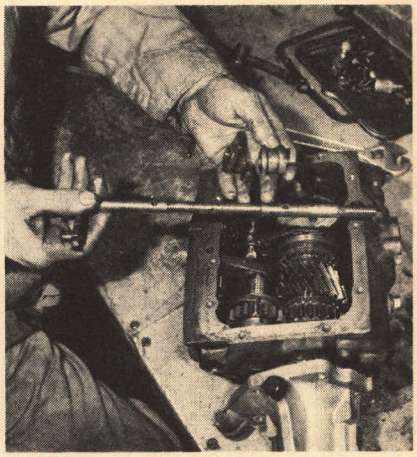


9. Now drive out reverse intermediate lever bedding bolt and remove the reverse speed shifter intermediate lever. The rest of Vega box is held together with drift pins.



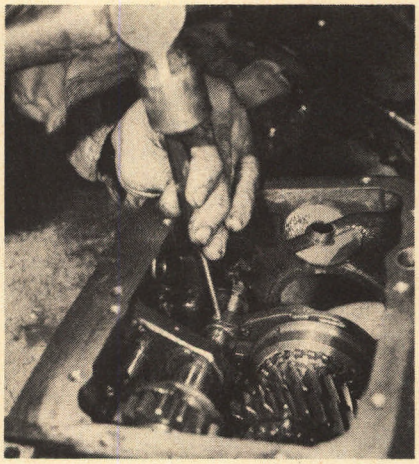
10. Remove the input shaft and the main drive gear from the front of the trans by pulling straight off. It may be necessary to rock the input shaft back and forth as you pull it forward.

11. Two drift pins hold the selector shaft in place. This one is easy to see and work on, but access to the other pin is gained through hole (A) in case, and punch size used is important.

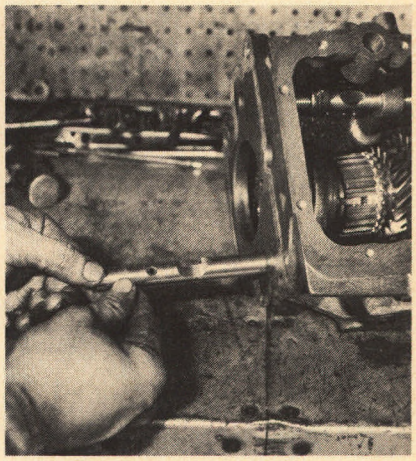


12. Once the drift pins are removed (use ⅛-in. pin punch), the selector shaft can be pushed out of the trans case and the intermediate levers removed with it. Check levers for wear.

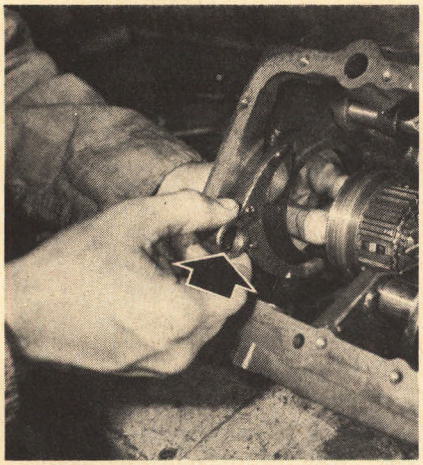
13. Remove the two aluminum gearshift interlock detents from the top of the case (A). Pry out plugs with care to prevent damage to them and remove springs and balls.



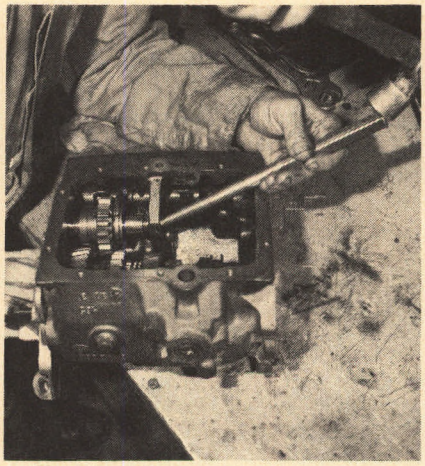
14. Knock out drift pin holding 3rd/4th shift fork to shifter shaft. Use care because the shift forks are rather brittle metal and can be easily broken by a misplaced blow.



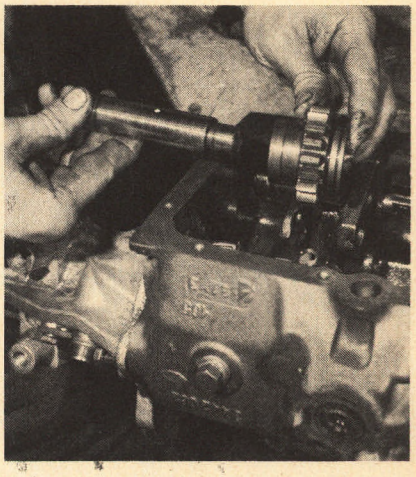
15. Turn the extension housing until the shifter shaft is exposed, and then tap shaft lightly from the rear of the case until it can be pulled out through the front and removed.



16. With shifter shaft removed, 3rd/4th fork is angled off clutch face and out of case. Rounded notch at shaft hole part of fork must face rearward when replacing fork in case.

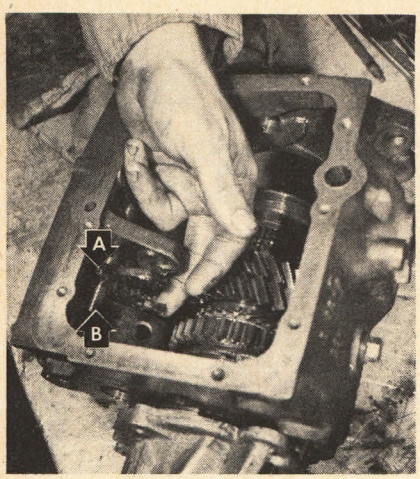


17. A special tool is made for driving reverse idler gear shaft rearward and out of the case, but if you don't have this tool, you can do the same with a punch and careful tapping.

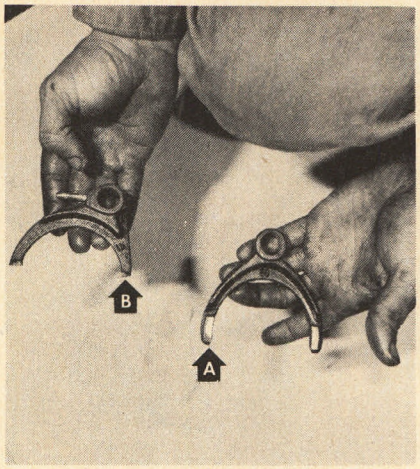


18. Shaft uses a lock ball—watch for it when you remove the shaft and reverse idler gear from trans case. Inspect the shaft for burrs and the gear for worn or damaged teeth.

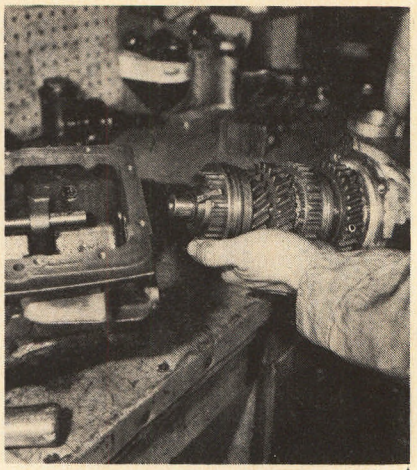
HOW-TO: Vega (Opel) 4-speed Overhaul



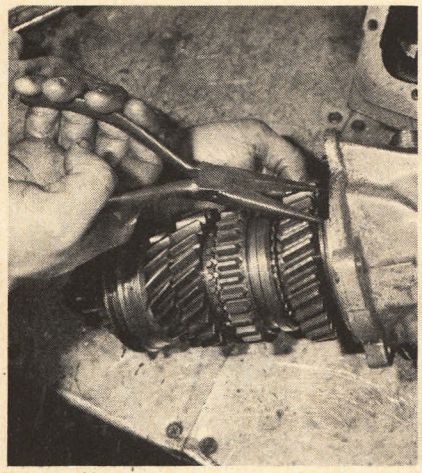
19. The reverse speed shift fork will remain in case unless drift pin (A) and shaft (B) are removed. If the fork is not damaged, there's no reason to remove this one from case.



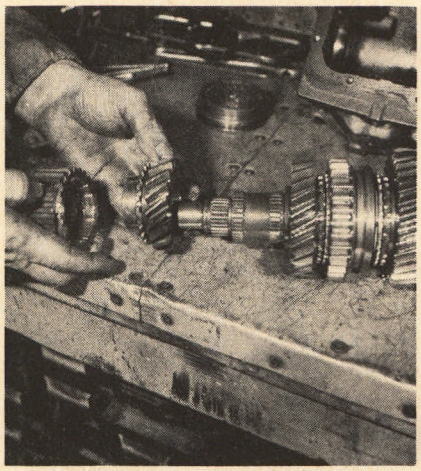
20. Forks are not interchangeable. The 3rd/4th fork (A) is worn, but legs on 1st/2nd fork (B) are broken. This is more likely to happen during disassembly than during operation.



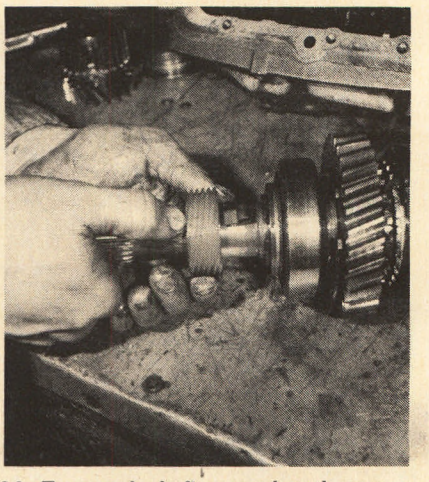
21. Now withdraw the mainshaft assembly and extension housing from the rear of the trans case. The gear shifter sleeve will be pulled off as you remove the shaft.



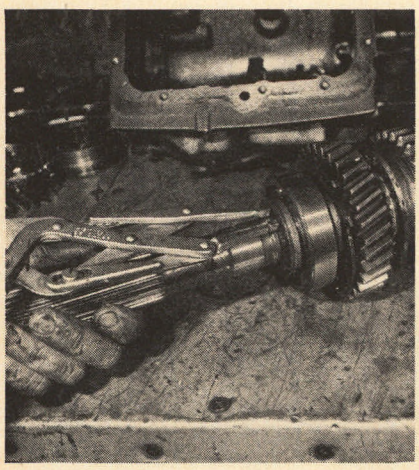
22. When you are ready to remove the mainshaft from the extension housing, you'll have to squeeze the mainshaft bearing snap ring together and then draw it forward.



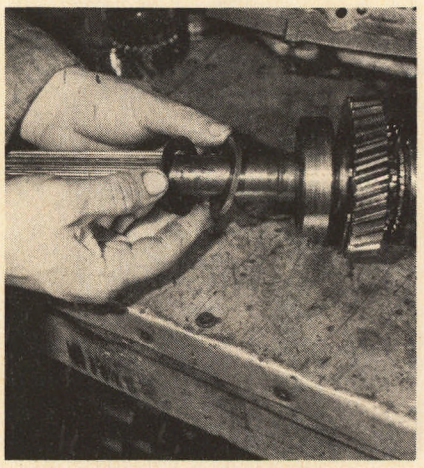
23. After removing the snap ring at front of 3rd/4th clutch assembly, clutch and 3rd gear can be withdrawn from the mainshaft. Do everything you can to keep the clutch intact.



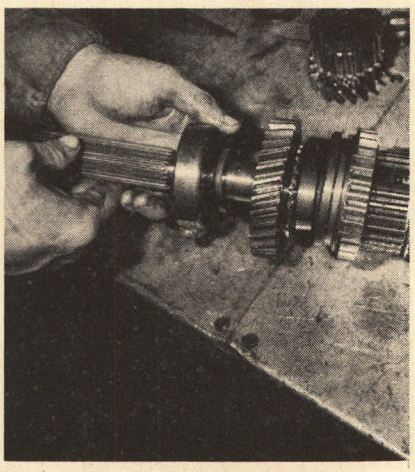
24. Turn mainshaft around and remove the snap ring and washer located behind the speedometer drive worm gear. Pressure clip with lock ball beneath is exposed as gear slides off.



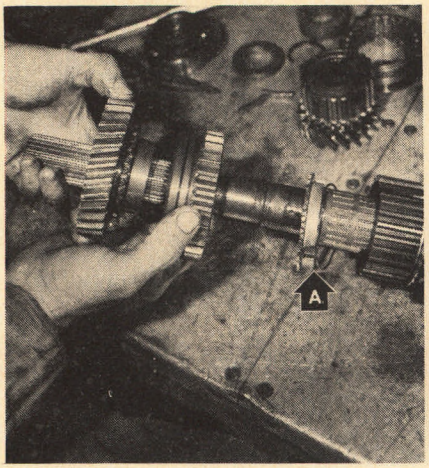
25. Another snap ring is removed to continue disassembly of the gear tower from the rear of the mainshaft. Snap ring pliers are great help when you are doing manual trans work.



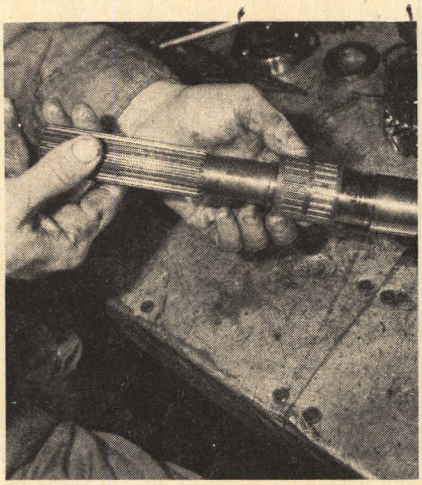
26. Washer and spacer are removed from rear of mainshaft inner bearing in that order. Bearing may have to be removed with puller. However, it usually slips right off.



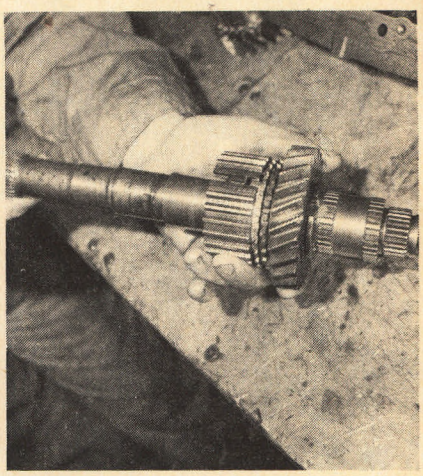
27. The bearing, bearing snap ring and spacer can now be removed from the shaft. Note that the spacer cone faces toward the bearing instead of the 1st gear assembly.



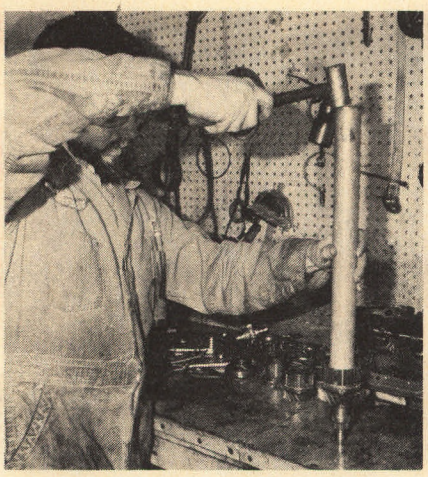
28. When the 1st gear is pulled free from the 1st/2nd gear speed clutch, the clutch will come apart. Remove parts shown, then blocking ring and clutch key spring (A).



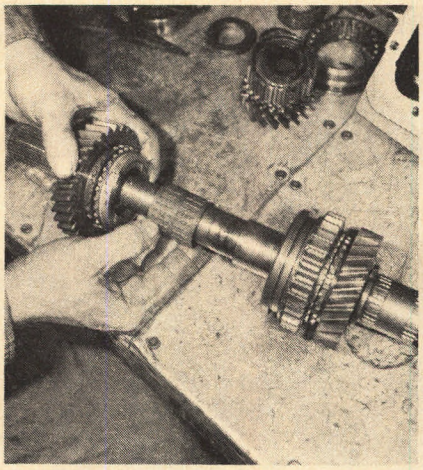
29. This 1st speed needle bearing sleeve comes off next and should be inspected carefully for loose, worn, missing or damaged bearings or deformed sleeve.



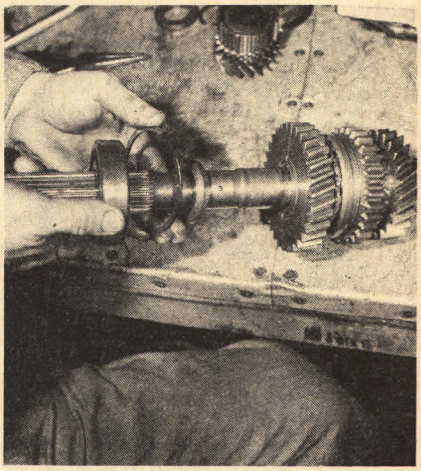
30. The remainder of synchro-clutch and 2nd gear are removed from the mainshaft, completing disassembly. Be sure and inspect all the gear faces and teeth for damage.



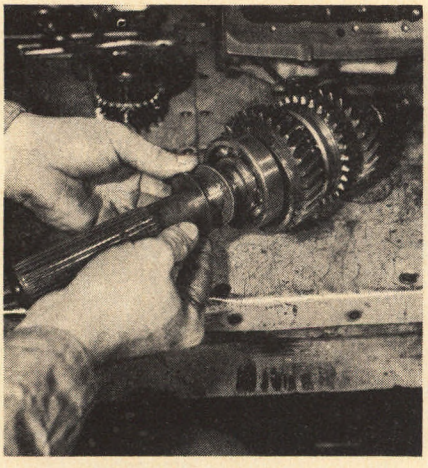
31. Reassembly of the mainshaft begins with the 2nd gear and the 1st/2nd speed synchro-clutch assembly. Set into position against the stop ring on the mainshaft.



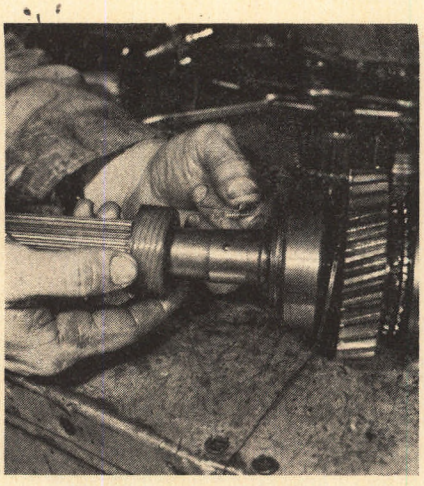
32. Replace 1st speed needle bearing, blocking ring and 1st gear. Make sure that the blocking ring cutout engages the synchro-clutch properly and fits into place easily.



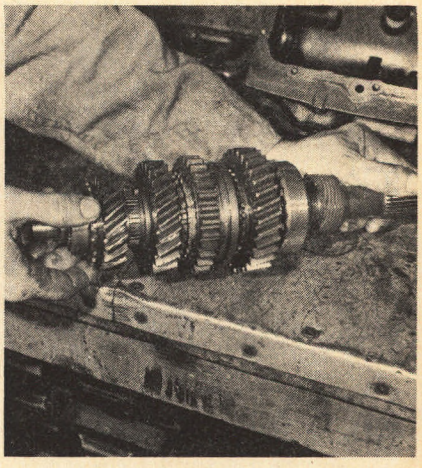
33. The mainshaft spacer (cone toward bearing), the bearing retainer snap ring and the inner bearing are replaced next. The bearing should seat easily without need for lubrication.



34. The spacer and washer are then fitted into position behind the bearing. Be sure to inspect the bearing for cracked races, worn balls and other defects before replacing it.

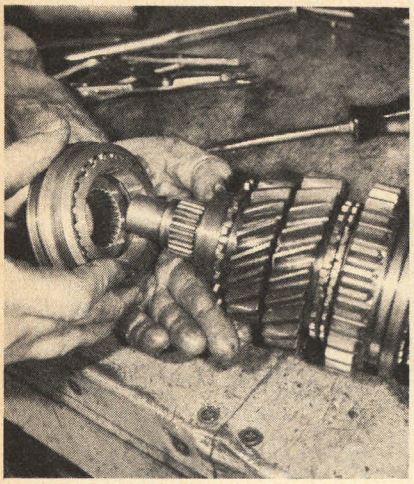


35. Metal spring clip slips under the speedometer drive worm gear. Lock ball is inserted in shaft and gear/clip positioned over it, then the rear snap ring is replaced and secured.

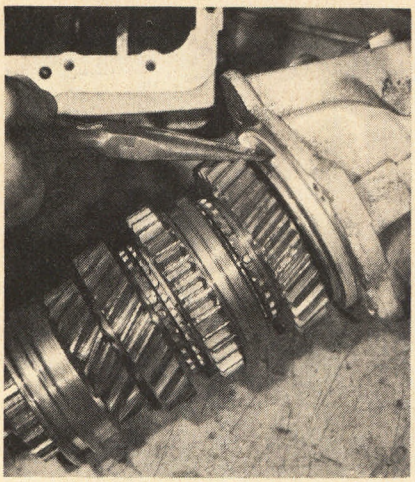


36. The next step is to turn mainshaft around and install 3rd gear and blocking ring, seating against the stop ring on shaft. Gear cone must face toward end of shaft for proper mesh.

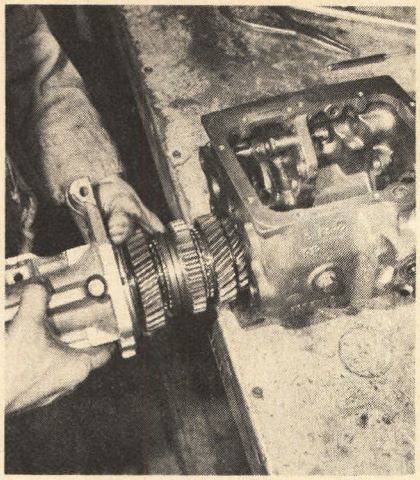
HOW-TO: Vega (Opel) 4-speed Overhaul



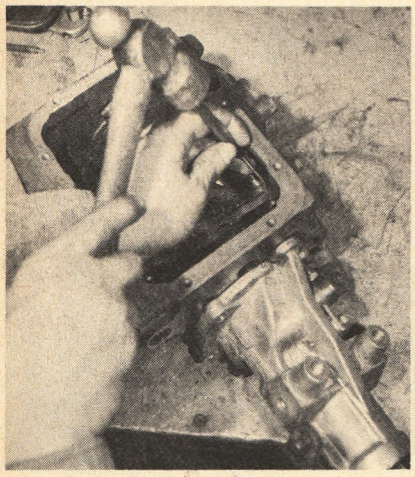
37. The 3rd/4th synchro-clutch assembly is fitted into place, seated and secured with the gear shifter sleeve snap ring, completing reassembly of gear tower on the mainshaft.



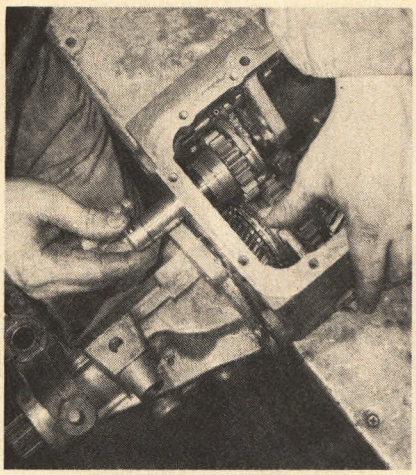
38. Place mainshaft assembly in the extension housing up to its stop, and then secure in place with the mainshaft bearing snap ring. Make sure that the ring engages completely.



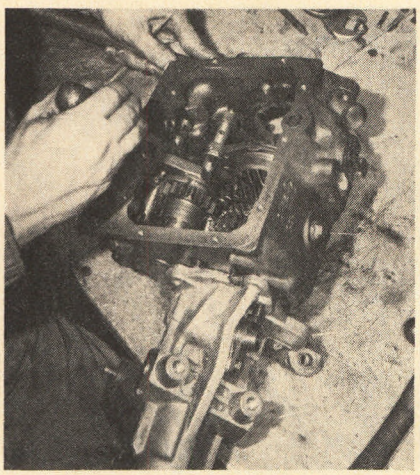
39. Reinstall mainshaft in trans case, and then fit the main drive gear and input shaft through front of case to engage mainshaft. Use a twisting motion to fit together.



40. Fit the 1st/2nd gear shifter shaft into the transmission case and through the shift fork; then rotate until the holes line up properly. You are now ready to reinstall the drift pin.

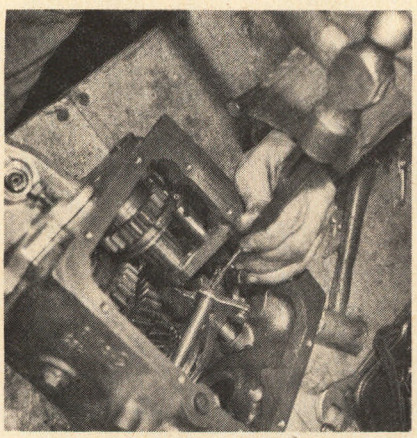


41. Place lock ball into reverse idler gear shaft and push shaft through hole in rear of the transmission case to pass through reverse idler gear with groove end toward front.

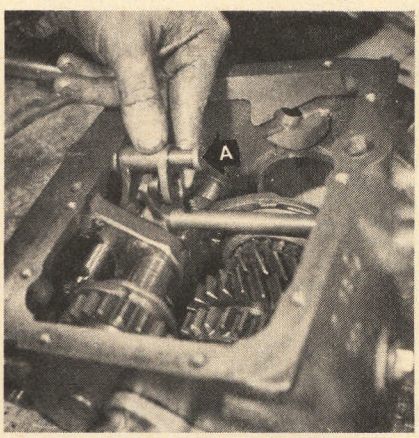


42. Reinstall 3rd/4th speed shifter shaft through trans case and shift fork. Use a screwdriver to position the fork while turning the shaft until drift pin holes line up properly.

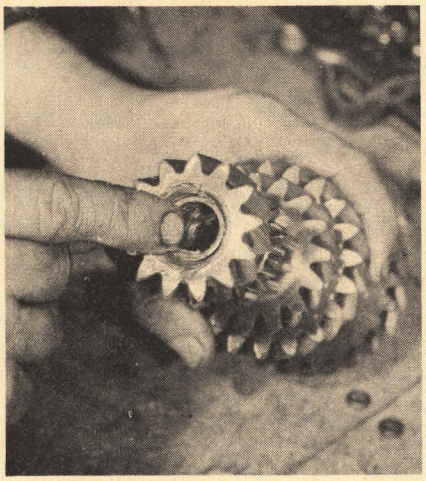
43. The drift pin holding 3rd/4th shifter fork to shaft is replaced. Be sure and use 3/16-inch or larger punch when reinstalling all drift pins in this particular transmission.



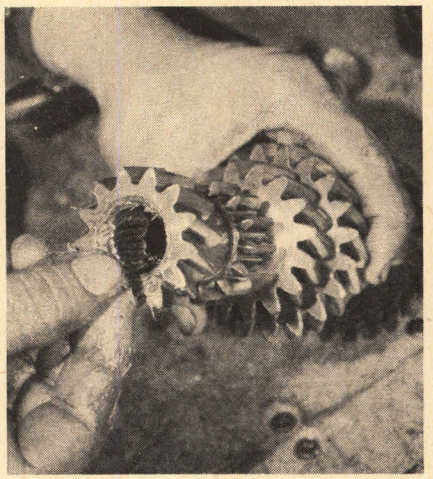
44. Insert new selector shaft oil seals in the appropriate holes on both sides of trans case, then slide the shaft into the case and through the intermediate lever. Install drift pin.



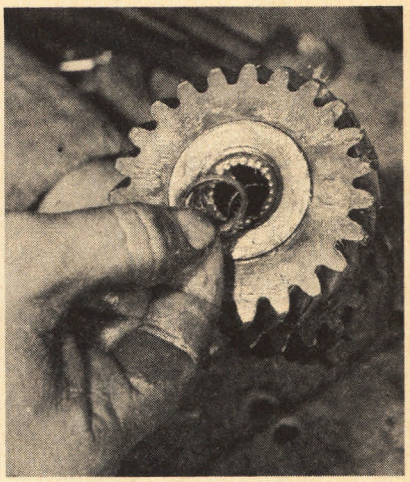
45. The reverse shifter intermediate lever is fitted into place to engage the arm on the 3rd/4th intermediate lever and the bedding bolt (A) is driven into transmission case to secure lever.



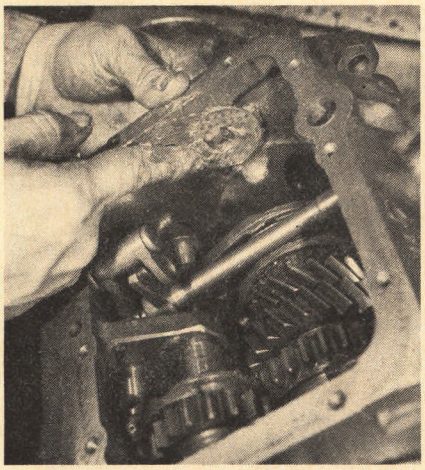
46. The countergear uses one set of roller bearings between two spacers at each end. Be sure and coat inside of gear with grease, and then set first washer in position.



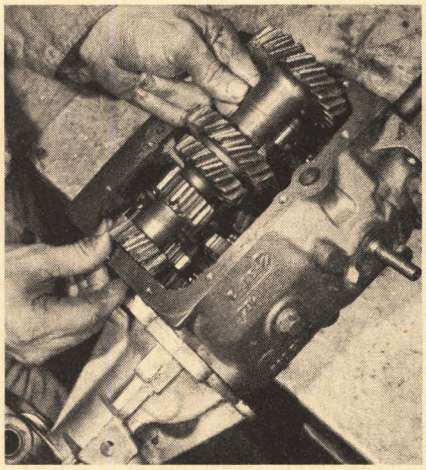
47. Place one row of roller bearings in the end of the countergear. Grease makes the use of a dummy shaft unnecessary in reassembling the gear for reinstallation.



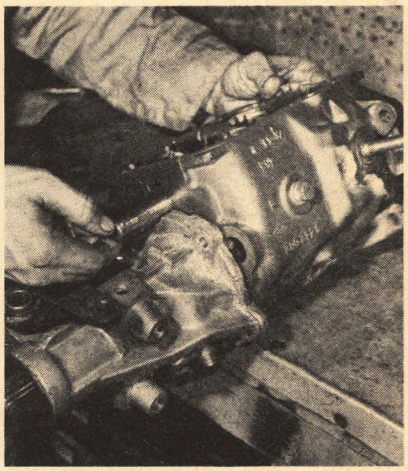
48. After the bearings are positioned, you can place the second spacer coated with grease over them. Then repeat this procedure at the other end of the countergear in preparation for replacement.



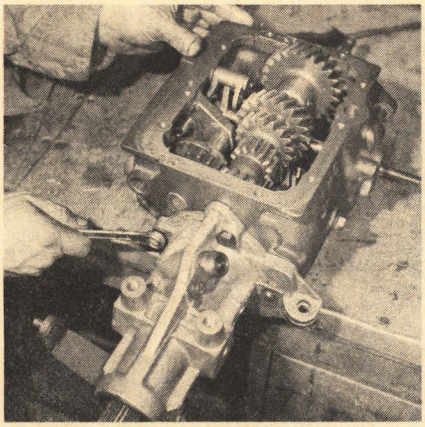
49. Now you can coat the countergear thrust washers with grease and stick to transmission case. The thrust washer lugs must fit into the slots provided inside the case.



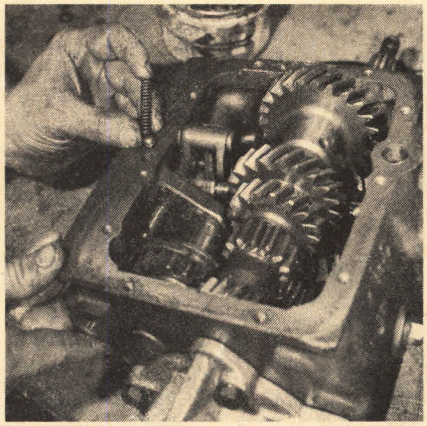
50. The next step is to place the countergear unit carefully in the trans case. This is the only real advantage of "bottom-loader" design as you don't have to struggle here.



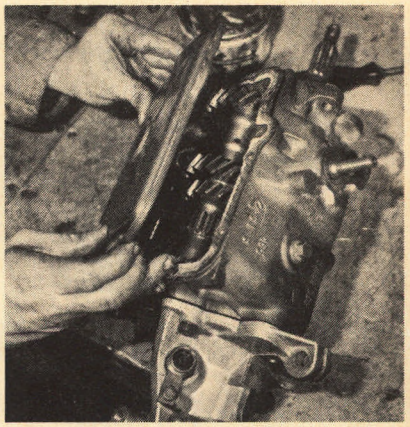
51. Place the lock ball in the countershaft recess and slide the shaft through the countergear from the rear of the case. Tap the shaft with a mallet until it's flush with the case.



52. Now rotate the extension housing until the bolt holes line up with the transmission case. You can then replace the bolts and torque each to 21 ft.-lbs. (Coat with a sealing compound).



53. Replace the gearshift interlock detent balls, springs and plugs at the top of the case; then turn transmission case over and insert reverse interlock detent ball, spring and plug.



54. Screw the backup light switch into the rear of the case; then replace the cover and gasket. Tighten all 10 cover screws. You have just completed the Vega 4-speed overhaul.

Automatic Transmission

There is no reason to be afraid to work on an automatic transmission. Once the thing is out of the car and you have a nice big bench or clean floor to work on, it's simply a matter of undoing some bolts and nuts, prying out a few snap rings, and surprising yourself that it comes apart so easily. The hardest part about automatic transmission work is getting the darn thing out of the car. It is so big, clumsy, and heavy that you aren't about to lift it out of there without some help, either in the form of some husky friends or an automatic transmission jack. Dropping the transmission would be a disaster, maybe to your foot but surely to the transmission itself because many of the cases are made of aluminum.

Before tackling your automatic you should get a manual that gives detailed explanations and pictures of the disassembly procedure. The manuals are usually available through your local auto parts store or car dealer. Each one of the manuals will be almost as thick as this book and well worth the several dollars that you will have to pay for it. Without the specialized manual you will be faced with a hit-or-miss proposition, and almost surely your transmission will not go back together the way it should.

Overhaul and repair of any automatic transmission is well within the realm of an amateur mechanic's skill, since it is primarily a remove-and-replace procedure (much the same as manual transmissions). However, the average mechanic faces an automatic transmission repair with some trepidation, simply because he does not fully understand the inner workings of the magic box. Whether the model is an early Hydro, a 2-speed, a Dynaflow, or the modern 3-speed, the same basic design principles are involved.

AUTOMATIC TRANSMISSION DESIGN

In essence, all automatics currently popular include one or more sets of planetary gears, one or more fluid couplings or a torque converter, and control valves to direct hydraulic fluid. The control systems may vary considerably, since an automatic transmission may be controlled manually by the driver (shifting lever), hydraulically by throttle movement, by the engine vacuum, by speed-sensitive governors, or by an electrical device. Additionally, two or three of these types of controls might be included on any one transmission.

The biggest difference between automatics is the type of connection between engine and transmission. The Hydra-Matic of earlier days used a fluid coupling, while the later transmissions rely on the torque converter. The advantage of a torque converter is simple; through ingenious routing of the fluid, considerable torque multiplication can be gained when a car needs it most—at standstill and during the first few moments of movement.

Within either the simple fluid coupling or the torque converter, a pump located near the center of the revolving wheels distributes oil outward through vanes. As the engine rpm drops below a certain point near idle, this hydraulic pressure is not enough to overcome the static weight of the vehicle. However, as engine rpm increases, the hydraulic pressure also goes up. The oil thrown across reaction vanes then begins to turn the transmission smoothly, with a certain amount of slippage. At high engine and hydraulic pump rpm, the driving and driven members of the coupling or converter are operating at a near 1:1 lock-up ratio.

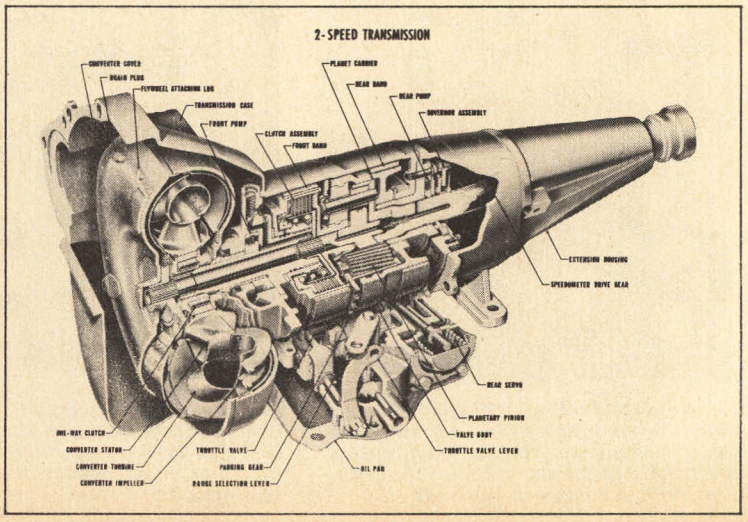
From the driven member of the converter or coupling, power is transferred through a shaft to clutch/drum assemblies inside the transmission housing. These clutches are similar to the single large clutch common to the standard transmission in that they function solely on the principle of friction. Planetary gearsets are connected to the clutch packs, producing the final gear ratios that exit through the transmission output shaft. Of all the workings inside an automatic transmission, the amateur would have most difficulty with the valve control body. For this reason, it is advisable to purchase a new valve body should one be damaged. There is very little choice with the torque converter, as repair of such must be left to the professional shop equipped with specialized tools.

It is virtually impossible to present detailed illustrations on how to assemble and/or repair all automatic transmissions in current use, for this would require the entire length of this book. Rather, we are presenting studies of two popular transmissions that will satisfy a great many readers: the Chevrolet Turbo Hydra-Matic 400 and the Ford C-4 Cruise-O-Matic.

1. Automatic transmissions look scary to the beginner, but there's no reason why any amateur mechanic can't handle the job once he understands the basic principles involved.

2. The illustration shown here is of a 2-speed Ford-O-Matic. Callouts are invaluable because they name all of the components.

1. Removing Auto Trans Cover



2. Ford-O-Matic Cutaway

The other member of the "big three," Chrysler Corp., also has a modern 3-speed automatic transmission, and like the GM Turbo Hydra-Matic and Ford Cruise-O-Matic, Chrysler's 3-speed is available in both light and heavy-duty models. The A-904 TorqueFlite sees light-to-medium duty in the whole Chrysler Corp. line-up, usually behind the 6-cylinder engines and small-block V-8's. Doling out the power flow from the larger V-8's is handled by the heavier-duty A-727 TorqueFlite. As with the differences between Ford's C-4 and C-6, and GM's Turbo Hydra-Matic 350 and 400, the light and heavy-duty TorqueFlites are almost identical in design, changed only where necessary to handle heavier loads.

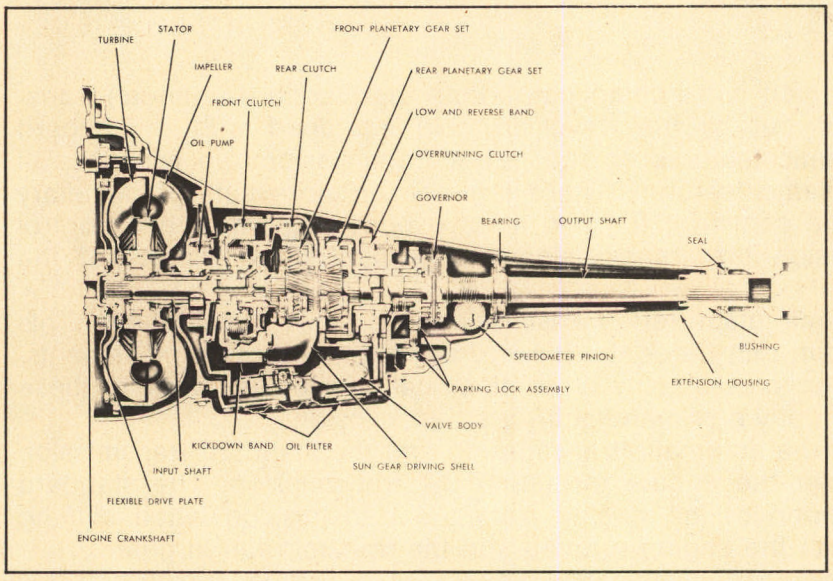
The converter housing and transmission case are cast integrally of aluminum and this one-piece design contributes to the TorqueFlite's low overall weight of about 160 lbs. with the converter installed. The "power play" through the transmission consists of two multiple-disc clutches, an over-running clutch, two servos and bands, and two planetary gear sets to provide the three forward ratios and one reverse. The sun gear is common to both planetary gear sets and connects to the front clutch by a driving shell splined to the sun gear and the front clutch retainer. Like the other automatic transmissions, the TorqueFlite's oil system includes a pump and a valve body to control and direct oil flow and pressure.

Chrysler's automatic transmission has been around longer than either the Ford or GM automatics, and refinements over the years to the same basic design have brought it a sound reputation for durability and trouble-free performance. First introduced in the 1956 Chrysler Imperial as the A-466, it has gone through numerous improvements yearly since then. Originally, the parking brake was on a drum mounted at the rear of the tailshaft, and this has been replaced with an internal sprag lock. Additionally, new organic friction material is used on the front and rear clutches, and extension housing lengths and mount locations have been standardized. Identification numbers on TorqueFlites were once cast on the bellhousing, but now are stamped on a pad at the left edge of the oil pan flange. The seven-digit number should be referred to any time parts are to be replaced on a TorqueFlite transmission.

3. Refined through improvements made on the basic design since introduced in 1956, the TorqueFlite transmission is one of the most dependable on the market (a 1975 A-727 is shown).

4. Cross-section of the Mopar torque converter illustrates the "heart" of a TorqueFlite automatic transmission. The interaction of turbine, impeller and stator provides the needed slip when a car is at idle, and torque multiplication during acceleration with full lock-up when cruising.

5. Minus the seals, gaskets, etc., this is the modern TorqueFlite with its internals out. Casting the case and bellhousing out of one piece of aluminum contributes to the overall light weight of the transmission.



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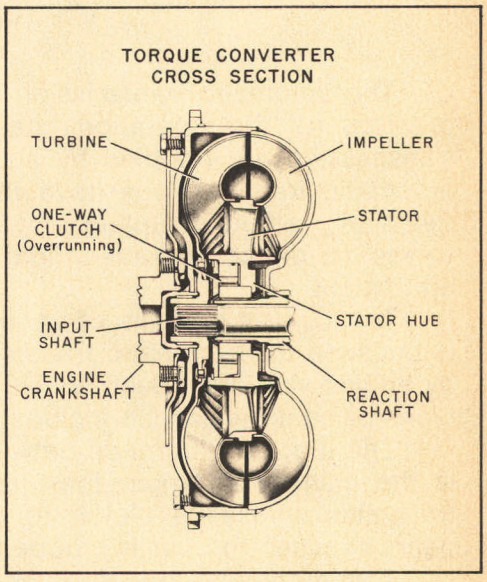

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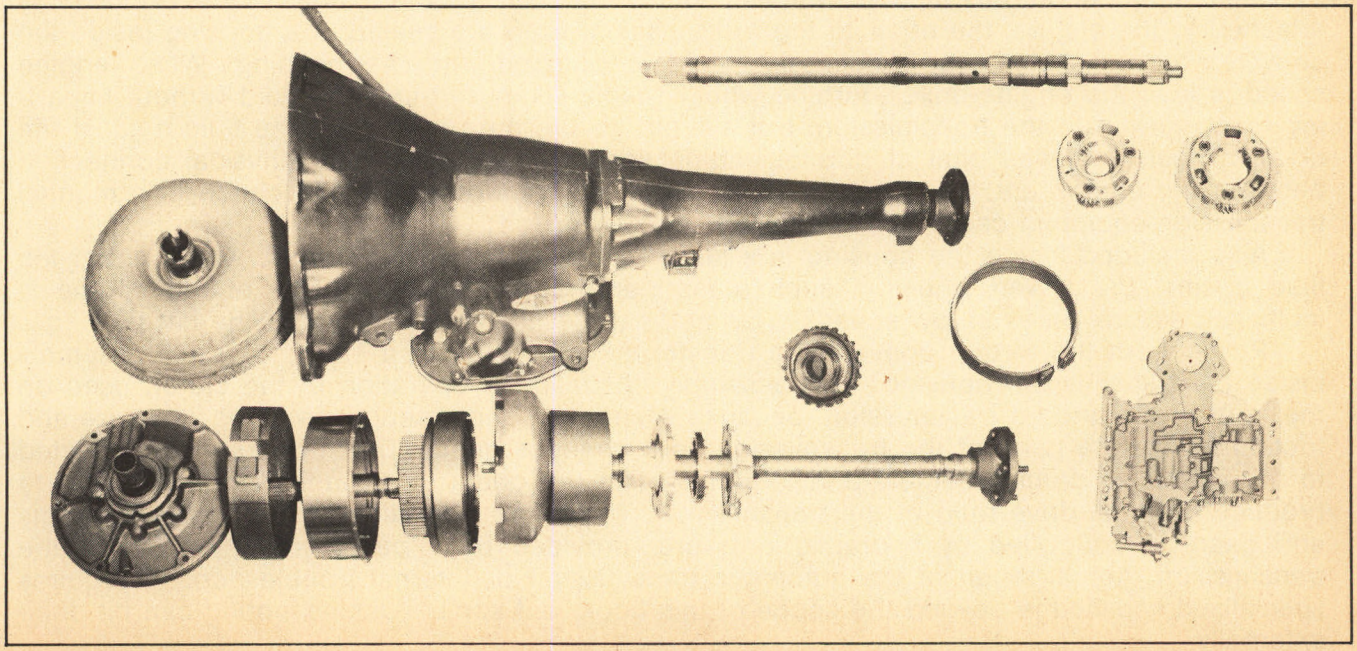
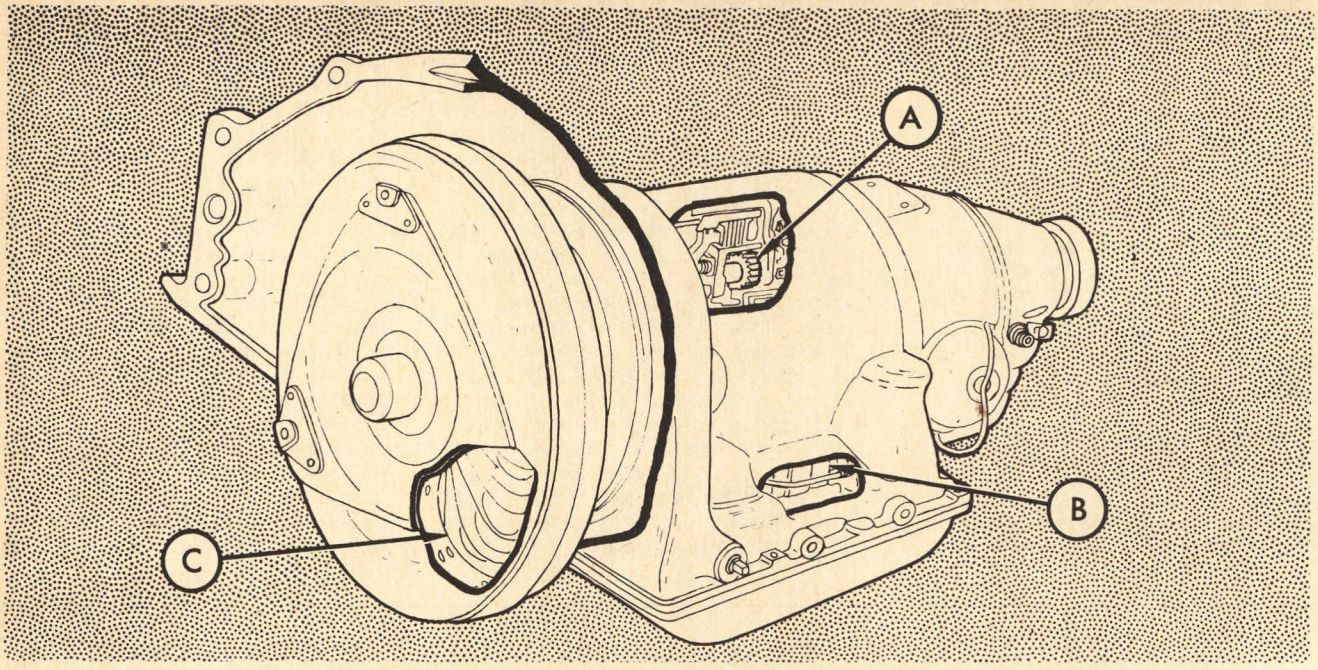

5

TROUBLESHOOTING AUTOMATIC TRANSMISSIONS



The automatic transmission is much more complicated than the standard (manual) transmission. All the operations carried out by the driver in cars equipped with a standard transmission are handled by automatic features on the newer transmissions. In essence, all automatic transmissions have the same features. There are one or more sets of planetary gears (A), a fluid coupling or torque converter (C) and a valve body (B), which has control valves to direct hydraulic fluid inside the transmission to operate different parts of the equipment.

The control systems of various manufacturer's transmissions may vary considerably. This is because the automatic transmission can be controlled hydraulically by throttle movements, by engine vacuum, speed-sensitive governors or by some electrical device. Any or all of these types of controls can be included on any one manufacturer's transmission.

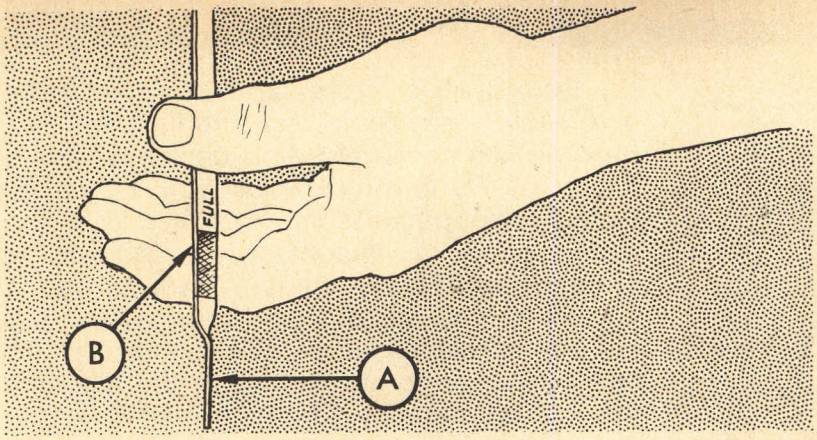
The biggest difference between the automatic transmission and the standard transmission is the manner in which they transfer the engine torque to the transmission. The standard transmission uses a clutch to disconnect the engine from the transmission when shifting gears or when the car is stopped with the engine running and the transmission in gear.

The automatic transmission uses a fluid coupling known as a torque converter. This hydraulic connection has finned wheels, something like turbine blades. One of these is attached to the engine, the other to the transmission. Both are sealed in a housing inside the converter cover. Automatic transmission fluid is pumped into the housing. When engine speed is low, the engine-driven turbine wheel simply slides through the fluid without imparting much torque to the transmission. But as rpm go up, the pressure of the fluid against the driven wheel increases until at normal engine speeds it is like a solid physical connection between the engine and transmission. This yields the same effect as the clutch in a manual transmission-equipped car.

Also included inside the housing is a set of fixed blades called stators, which direct the fluid against the driven wheel in such a manner that the torque output of the engine is multiplied several times at low speeds. This helps to get the heavy weight of the car moving.

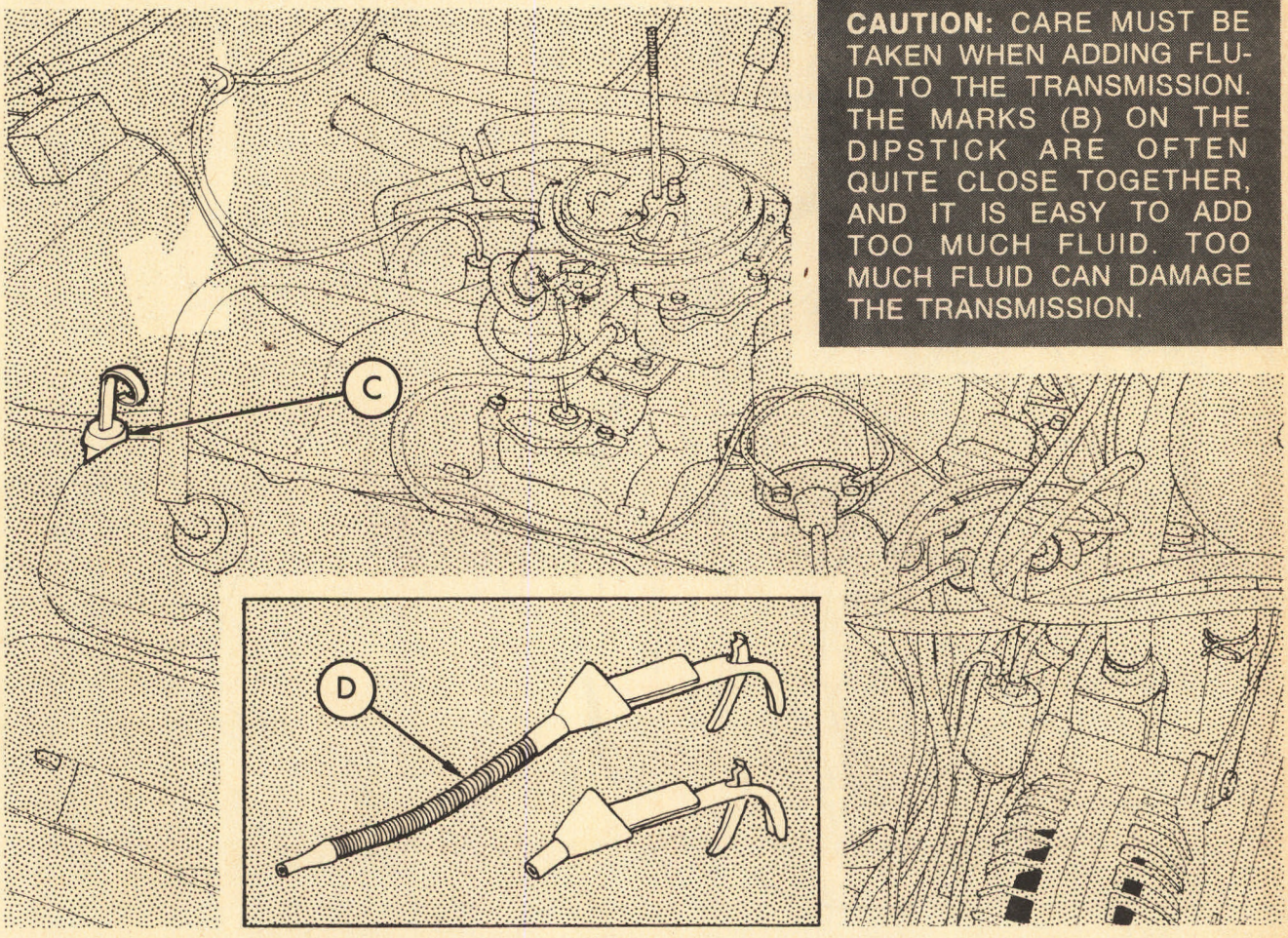
Power from the torque converter is transferred by a shaft to a clutch or drum assembly inside the transmission housing. This assembly is similar in operation to the clutch used on the front of a standard transmission, because it engages and disengages using pressure and friction to operate parts of the transmission as it changes gears. These gears are connected to the clutch or drum assembly and intermesh like the gears in a standard transmission to produce the final drive ratio of the transmission. The entire operation of the clutch or drums and gears is controlled by hydraulic pressure, provided by a pump which is part of the transmission. Actual repair of the automatic transmission or internal troubleshooting requires specialized knowledge beyond the scope of this book, but some troubleshooting can be done externally.

AUTOMATIC TRANSMISSION FLUID



The hydraulic fluid which the transmission uses is a special fluid. It can be checked by removing a dipstick (A) just like that used to check engine oil level. The transmission fluid level must be checked with the engine running and the transmission shift selector lever in the park ("P") position to get a correct reading. Make sure the engine has reached operating temperature before checking the fluid level. The dipstick is marked (B) like the engine oil filler dipstick.

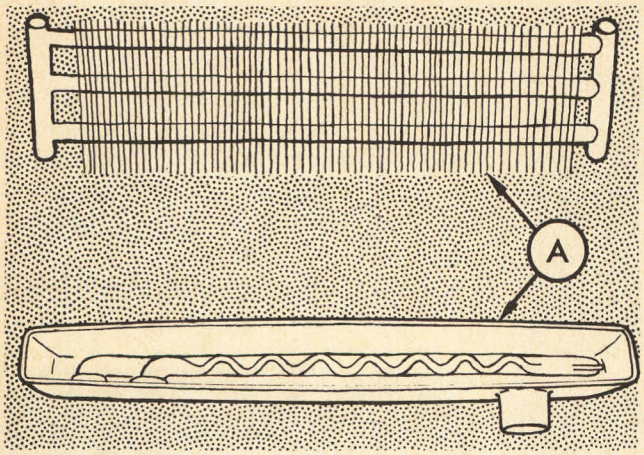
CAUTION: CARE MUST BE TAKEN WHEN ADDING FLUID TO THE TRANSMISSION. THE MARKS (B) ON THE DIPSTICK ARE OFTEN QUITE CLOSE TOGETHER, AND IT IS EASY TO ADD TOO MUCH FLUID. TOO MUCH FLUID CAN DAMAGE THE TRANSMISSION.



Fluid is added directly into the dipstick tube (C), using a funnel with a long, flexible tube (D). Fresh automatic transmission fluid is light pink, almost clear in color. If the color of the fluid on the dipstick is amber or brown, it should be changed. Dark brown fluid which smells burnt indicates transmission damage and the need for transmission servicing. This includes changing the transmission fluid, cleaning the transmission, changing all filters inside the transmission and inspecting and adjusting the bands. Continued driving risks incurring an expensive repair bill.

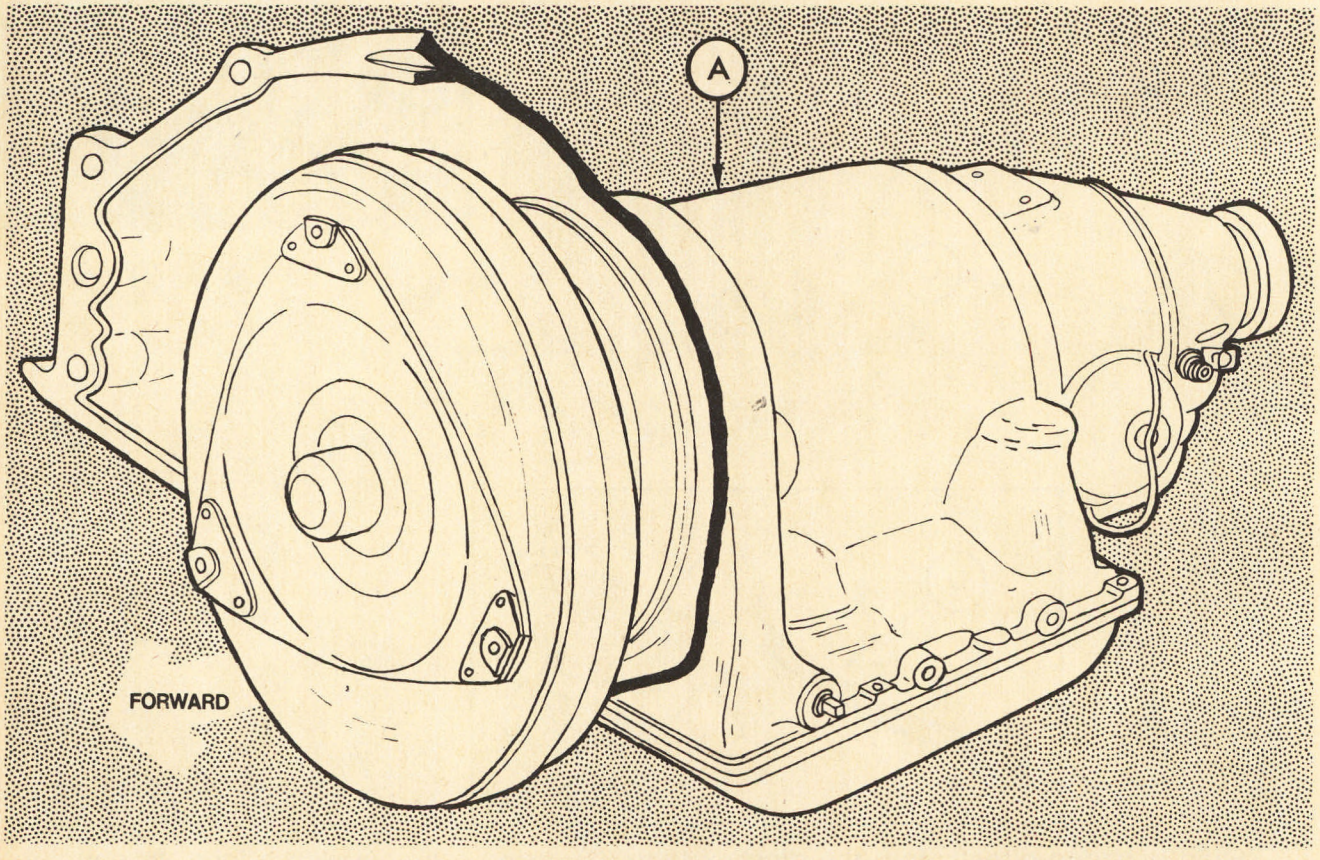
NOTE: EACH AUTO MANUFACTURER HAS A RECOMMENDED TRANSMISSION FLUID FOR HIS AUTOMATIC TRANSMISSION. NEVER SUBSTITUTE TRANSMISSION FLUID WITHOUT FIRST MAKING SURE THAT IT IS THE CORRECT TYPE FOR YOUR CAR. THE SALESMAN AT YOUR AUTO PARTS STORE OR THE DEALER'S PARTS DEPARTMENT CAN GIVE YOU THE INFORMATION YOU NEED. ALSO SEE YOUR OWNER'S MANUAL.

TROUBLESHOOTING AUTOMATIC TRANSMISSIONS



Burnt fluid or other signs of transmission overheating may indicate a problem with the transmission cooler (A). This device is usually a part of the lower reservoir tank of the radiator, although on some cars it may be an added piece of equipment not attached to the radiator. Fluid from the transmission is circulated through the cooler by a pump in the transmission and is cooled. Leaks in the lines or blockage of the lines or the tubing in the cooler can cause the transmission to overheat, especially when subjected to heavy loads such as trailer towing or long uphill climbs.

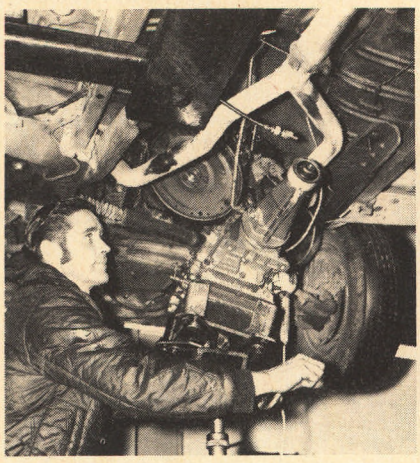
TYPICAL AUTOMATIC TRANSMISSION PROBLEMS



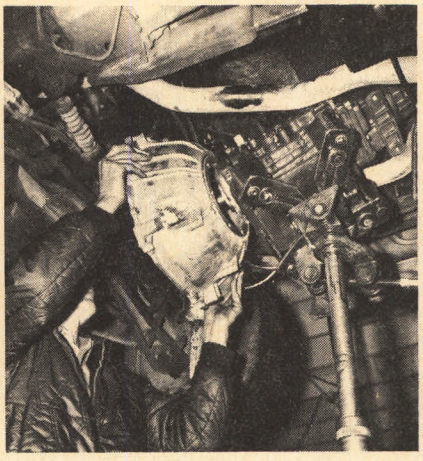
Because of the complexity of the automatic transmission (A), there is very little that the troubleshooter can do to remedy a problem without special tools and knowledge. The various shifting operations are controlled by so many different methods inside the transmission that the troubleshooter must have access to the shop manual to determine how his transmission is controlled and operated. Any malfunction of the automatic transmission should be examined by a transmission mechanic.

Some symptoms of automatic transmission trouble are similar to those of clutch problems in cars equipped with standard transmissions. One of the most common problems in transmissions is transmission slipping, in which the effect is much like that of a slipping clutch. This is an indication of future major transmission problems. Other trouble areas are: sticking in one gear or drive range, loss of transmission kickdown capability (passing gear), slipping in one gear but not another. All of these symptoms could lead to a major problem. Sometimes these symptoms can be eliminated by a simple transmission linkage adjustment. For more information on automatic transmissions, see your shop manual, Petersen's BASIC CLUTCHES AND TRANSMISSIONS or your local mechanic.

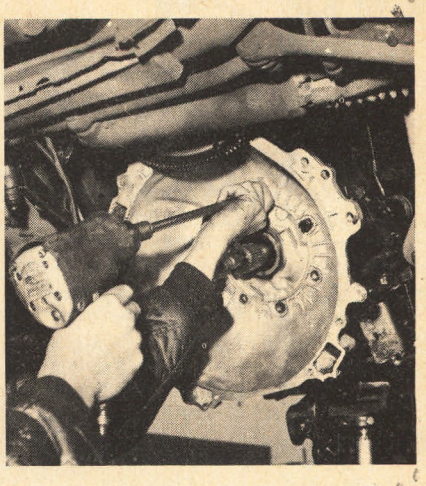
HOW-TO: Installing a C-4



1. Harold Shafer, R&R man at Steve's Transmission Service, 9012 Sepulveda Blvd., Sepulveda, Calif., installs a C-4 Cruise-O-Matic in a customer's car. Transmission jack is vital.

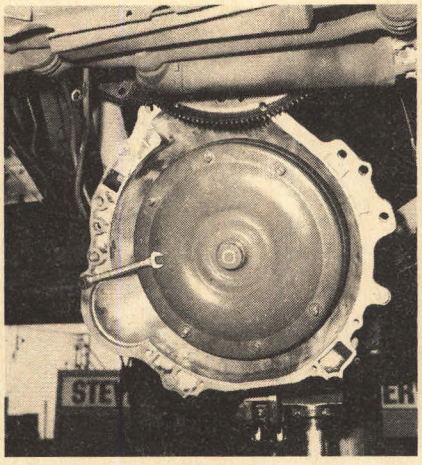


2. The bellhousing is a separate piece on the C-4, so trans is jacked up under car by itself, then housing is fitted in place. Jack adjustments allow trans movement.

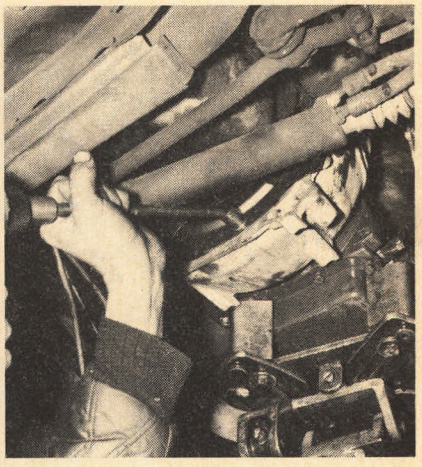


3. Bellhousing is attached to trans with bolts. While it is possible to build your own trans on a bench, a car hoist and jack are necessary for installing the transmission in the car.

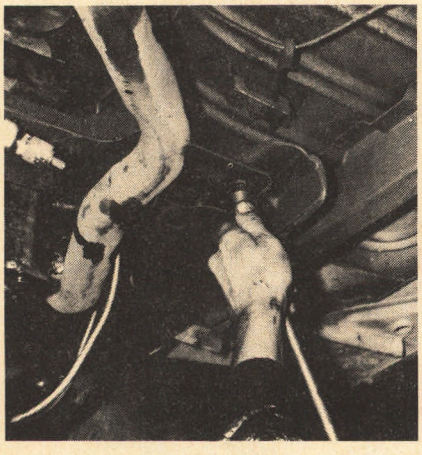
4. A new converter is installed in car along with rebuilt trans. If you have pulled or installed an automatic trans on your back, you'll appreciate use of a hoist and jack.



5. After the converter is wiggled into place, Shafer bolts an end wrench along one side of the bellhousing. This holds the converter in place until trans is raised up.

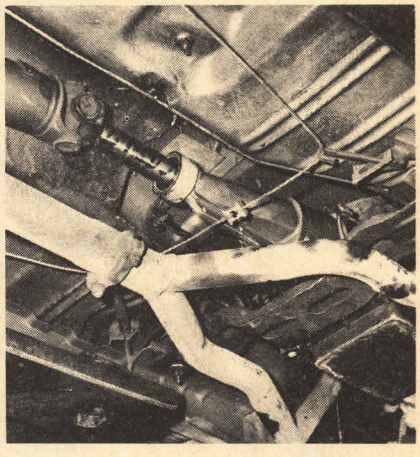


6. Converter is now attached to the starter ring, or flywheel, if you prefer. Four nuts secure ring to the converter which features built-in studs. Unit is rotated.



7. Removable crossmember is attached to the tail housing of the C-4 trans, then member is aligned with bolt attachment holes of chassis. Crossmember is now bolted secure.

8. Remaining operations involve installing oil lines that run to the radiator cooler (to cool the oil) and return, and connecting the speedometer cable and transmission shifting linkage.



9. A liberal amount of trans fluid is doused on forward driveshaft yoke which is then slid into tail of the trans. Rear U-joint is hooked, then trans is filled with fluid.

Automatic Transmission
Ford C-4

Of all the components in a modern automobile, probably none scare the average occasional mechanic more than the thought of tearing into an automatic transmission. Let's face it! Most of us know they shift OK by themselves for maybe 50,000 miles, and the fluid should be changed every 20,000 miles or so, along with the filter, before a teardown is necessary. But few of us really know how they operate, or how they come down and go back together. That's why we rely on shops such as Steve's Transmission Service to rebuild our automatic trans for us on those rare occasions when it is necessary. They are specialists, and know what they're doing. We don't. Right? Well, yes and "know."

They are specialists, and they do know what's happening. But that's no reason we can't learn to do the same things, like going through a transmission. Take the C-4 Ford Cruise-O-Matic and the Chevy Turbo Hydra-Matic boxes on the following pages. They are commonly used units, found in tens of thousands of cars. Maybe one is in your car, and it needs repairs. You know it does because it slips, or hesitates between gear shifts, etc. Now you're asking us, what next?

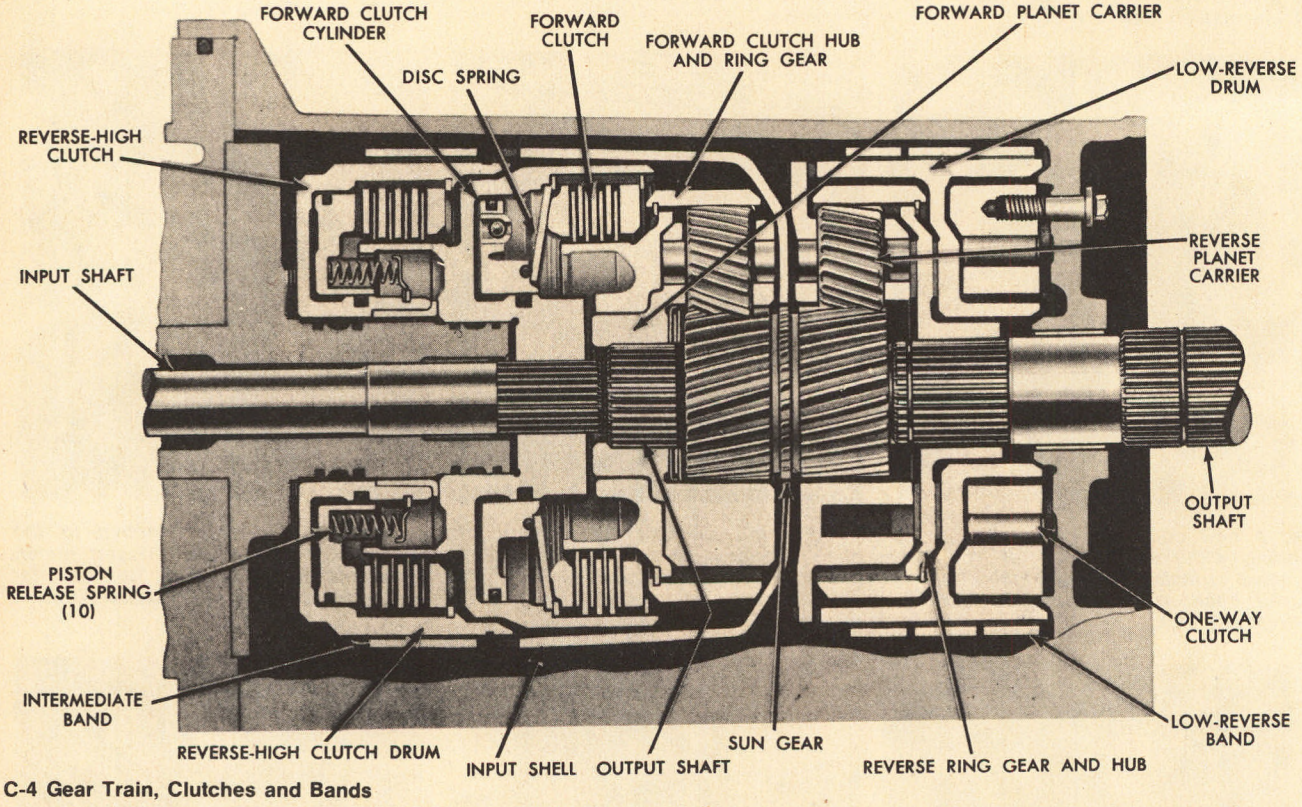
OK. By using this manual, and maybe a factory shop manual which will cost you another few bucks, you can easily pull your trans down with a minimum of hand tools. Parts cleaner can be used to wash all of the components, followed by solvent and an air hose to blow the parts and passages clean. New seals, O-rings, gaskets, bands and clutches are available over the counter at your local dealership, parts house, or trans repair service. Perhaps a good buddy will assist you, or at least give moral support. But if you are careful and take your time, there is little reason you can't rebuild your own automatic trans.

The hardest job comes in pulling and replacing the trans itself. Like the rest of us, you have a few sturdy jack stands that will hold the car a couple of feet off the garage floor, but you don't have a transmission jack handy. It's almost impossible to lift one of these boxes, or lower it, safely without a jack. The answer lies in going to a nearby tool rental agency to rent a small floor-type transmission jack. This is the only way to go to make the job easier and safer.

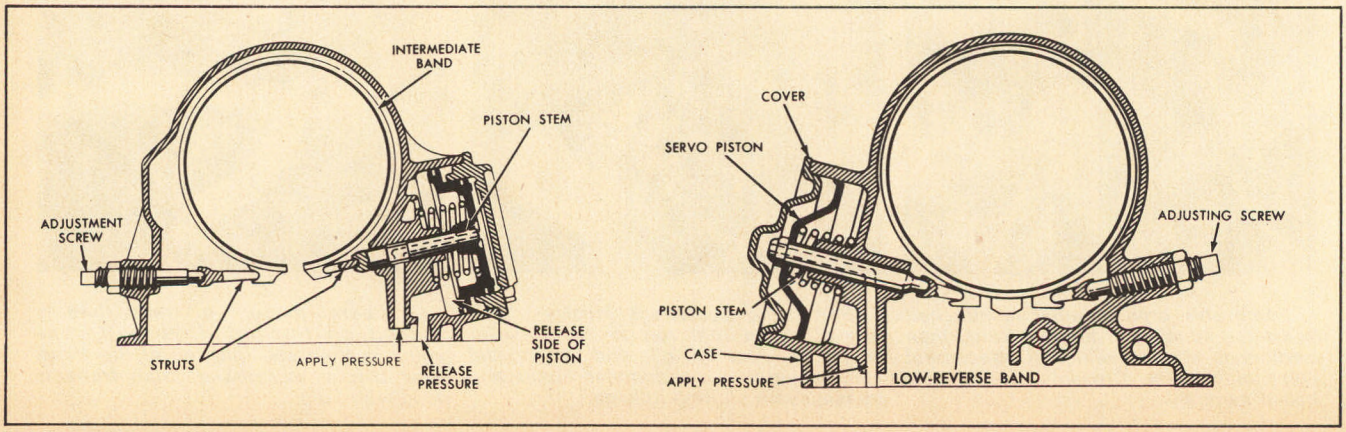
As we said, take your time, use this manual, and you can do it.

1. Detail drawing of C-4 gear train, showing clutches, band and drum.

2. C-4 intermediate band surrounds reverse-high clutch drum; it is adjusted by an external screw via struts. Low-reverse servo and band action is controlled by applied and released pressure on servo piston.

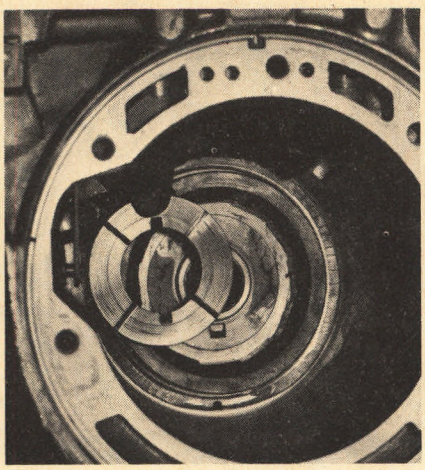


1. C-4 Gear Train, Clutches and Bands

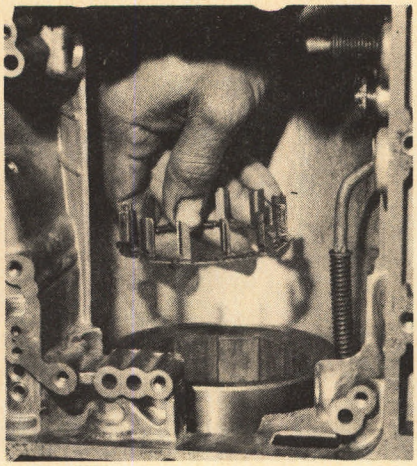


2. Intermediate and Low-Reverse Servo and Band

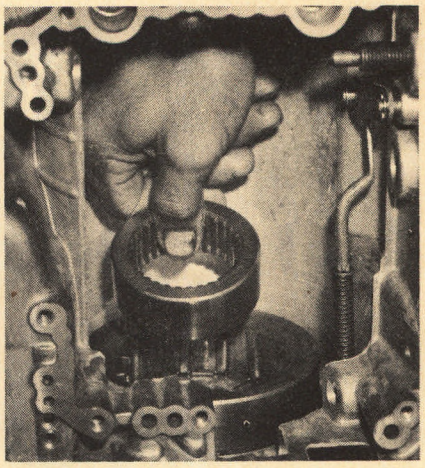
HOW-TO: Assembling a C-4



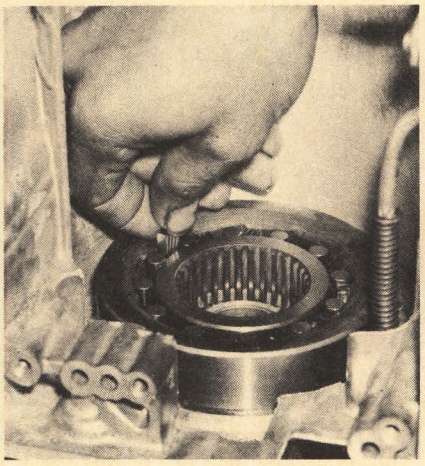
1. After thoroughly cleaning all components of the C-4 transmission, apply a little grease to the rear of the No. 9 thrust washer and then insert it in rear of trans case.



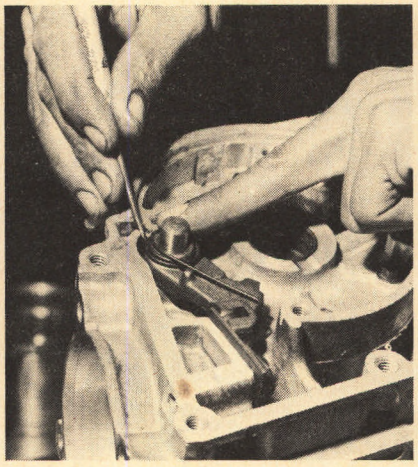
2. Following the installation of the thrust washer, insert the spring retainer cage that will support both rollers and springs of the one-way clutch. Inner race will follow.



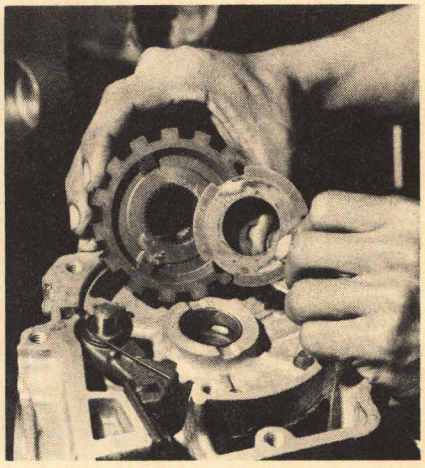
3. The outer race is already in the aluminum transmission case, so now we can install the inner race as shown; 12 springs and 12 rollers are used in the C-4 one-way clutch.



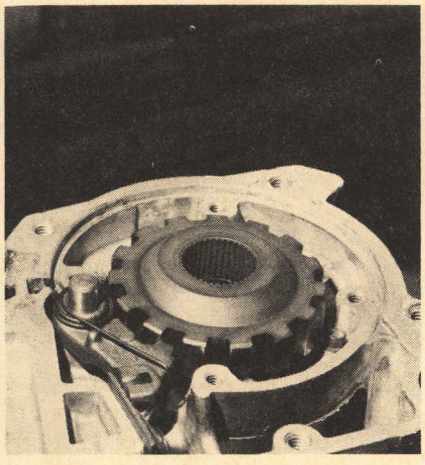
4. Now the 12 springs and 12 rollers can be installed in the one-way clutch. The two components are alternated between races, as shown, and provide low gear for the Ford C-4 trans.



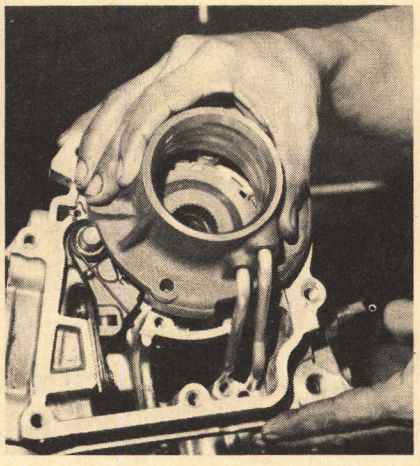
5. The parking pawl retaining pin is installed in the transmission case, then the pawl and pawl return spring are installed over the pin as demonstrated in this photo.



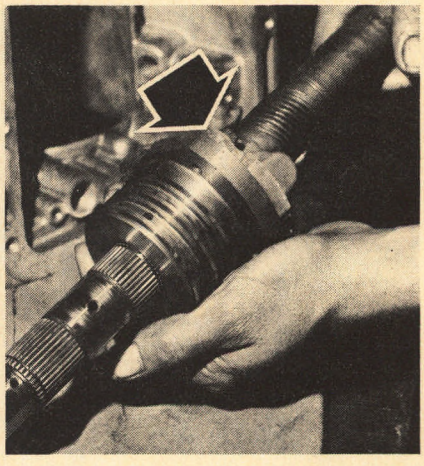
6. Thrust washer No. 10 is then attached to the parking pawl gear with the aid of a dab of grease. Reason for use of grease is to prevent washers from falling away.



7. The parking pawl gear with thrust washer attached beneath it is now positioned on back face of case. Once transmission is put to use, the grease will mix with trans fluid.

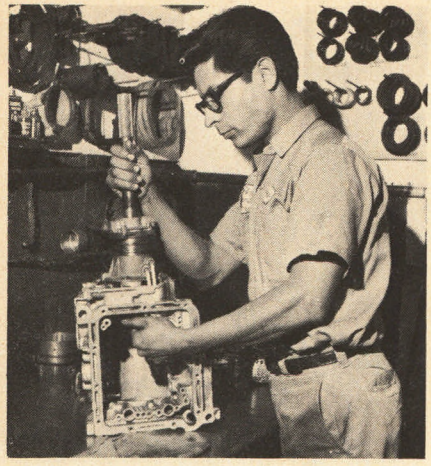


8. The governor distributor sleeve with oil delivery tubes is carefully installed on case. Tap sleeve down snug with a plastic-faced hammer; install bolts with torque wrench.

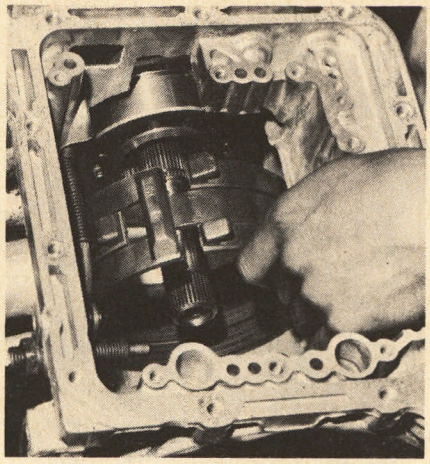


9. With the secondary governor bolted to the governor distributor, unit (arrow) is slipped over the transmission output shaft. Next, install snap ring to retain governor.

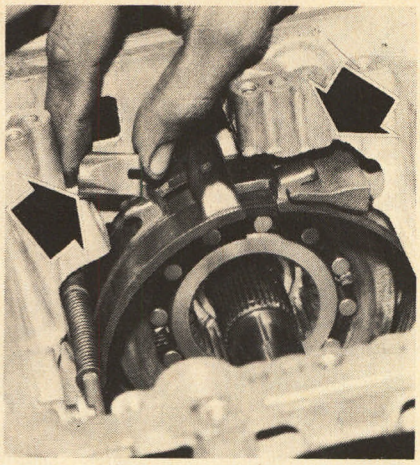
HOW-TO: Assembling a C-4



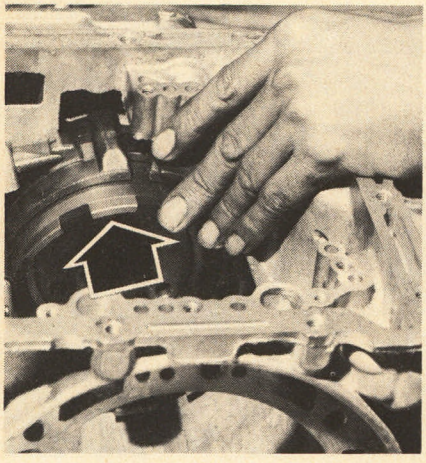
10. Steve Bustamente, an assembler at Steve's Transmission Service, Sepulveda, Calif., is installing the output shaft with the governor through the rear of the trans case.



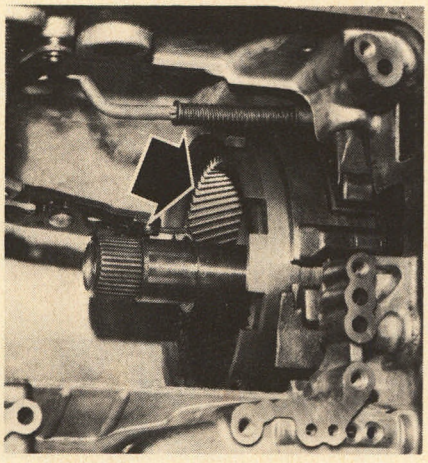
11. The rear, or low and reverse, band is installed through the front of the C-4 Cruise-O-Matic case. End of band for the small strut must face toward low-reverse servo.



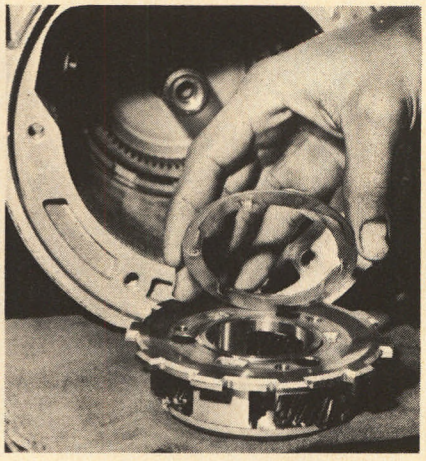
12. The two band struts (arrows) must be installed as shown, securing the low-reverse band in place in case. Struts lock in tangs on band and ride against aluminum case.



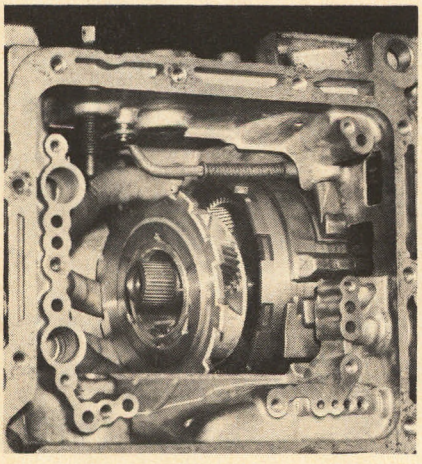
13. After a No. 8 thrust washer has been slipped into low-reverse drum (held firm with grease), the drum (arrow) is slipped through case and into the low-reverse band.



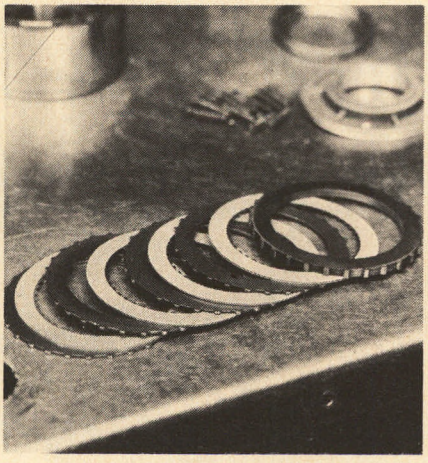
14. Reverse ring gear and the hub are then fitted (arrow) into the low-reverse drum and secured with a snap ring on the output shaft. Snap ring pliers are a must, here.



15. A No. 7 thrust washer is then installed on the rear of the reverse planet carrier (small end), held with grease. No. 6 washer (shown) is applied to front of carrier.

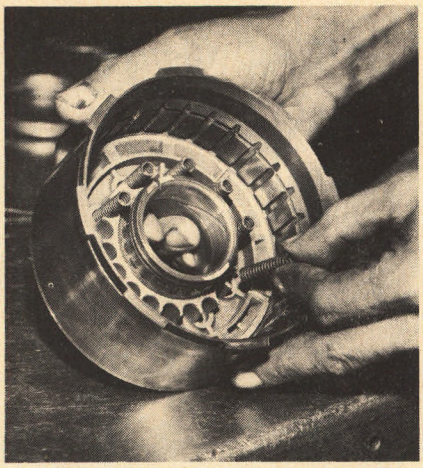


16. Now the reverse planet carrier can be installed in the reverse ring gear. Tabs of the carrier should be engaged with slots in the low-reverse drum, already in case.

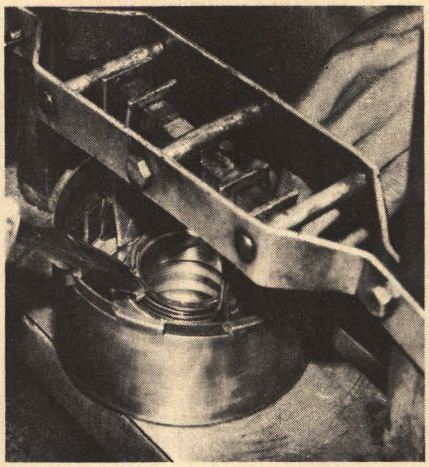


17. Lining-covered clutch plates are stacked alternately with steel plates in both clutch packs. These plates wear out, as do the bands, and must be replaced at overhaul.

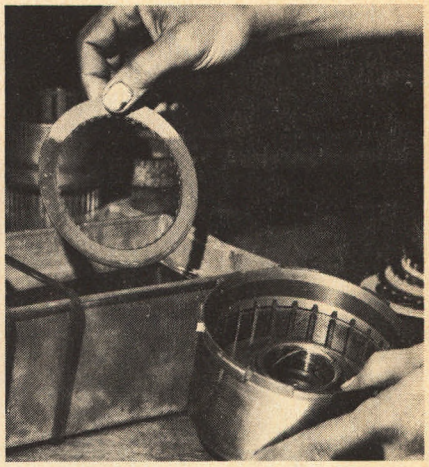
18. After the outer edge seal is clipped on to the reverse and high clutch cylinder piston, the piston seal is liberally coated with an STP-type of lubricant before installing.



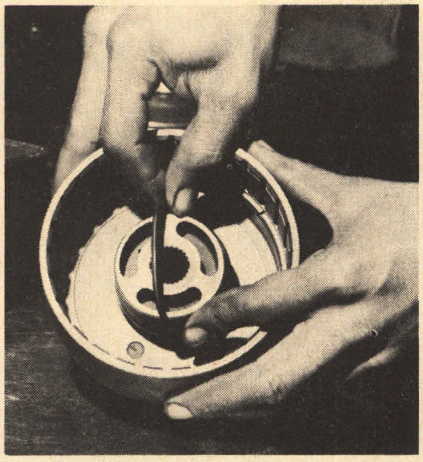
19. An inner seal is installed in clutch cylinder, then reverse and high piston is installed. Now the 10 piston return springs are set in place. They return piston to normal.



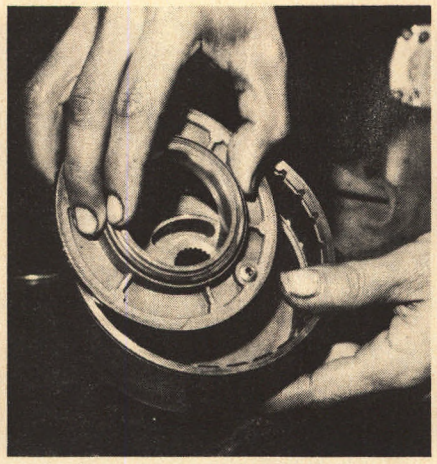
20. The spring retainer is held in place with a snap ring, then the clutch is placed in a press, so the springs can be compressed and snap ring installed in proper groove.



21. After the first driven plate is installed in reverse-high clutch, each alternate friction plate is dipped in automatic trans fluid. A clutch pack snap ring holds them.



22. The inner piston seal of the forward clutch cylinder can now be installed. Next, the outer clutch drum seal is installed on the piston and the unit lubed completely.

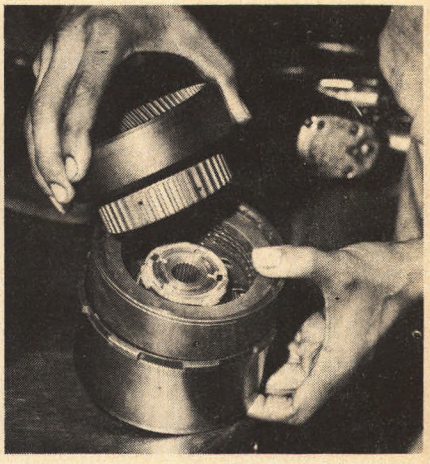


23. At this juncture, the piston is installed into the forward clutch cylinder, rim outward. One must use caution to make sure that all of the O-ring seals are installed and lubed.

24. The steel ring shown is then installed on top of clutch piston. Make sure clutch piston and cylinder are free of scoring or burrs. Use crocus cloth to remove imperfections.

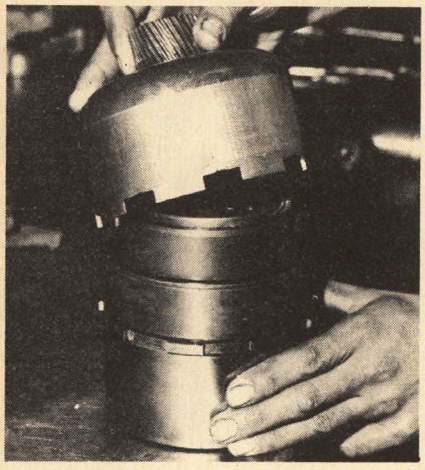
25. The disc, or diaphragm, spring is now installed in the clutch cylinder, concave side up, followed by installation of the snap ring, which will hold the disc in place.

26. The lower pressure plate is installed first, followed by alternating drive and driven plates, and finally the upper pressure plate and then the snap ring which holds the assembly together.

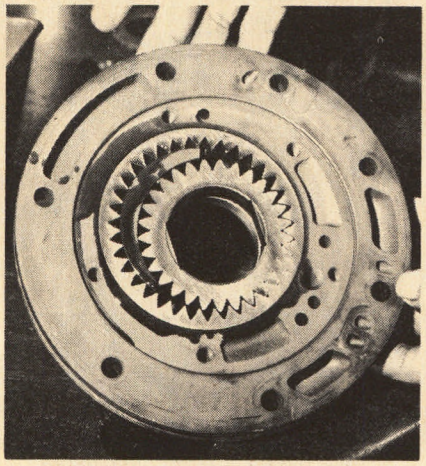


27. A No. 3 thrust washer is placed atop the forward clutch, then unit is stacked on reverse-high clutch drum, followed by assembly of the forward clutch hub and ring gear.

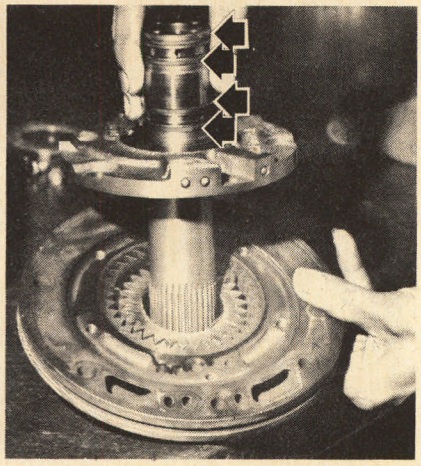
HOW-TO: Assembling a C-4



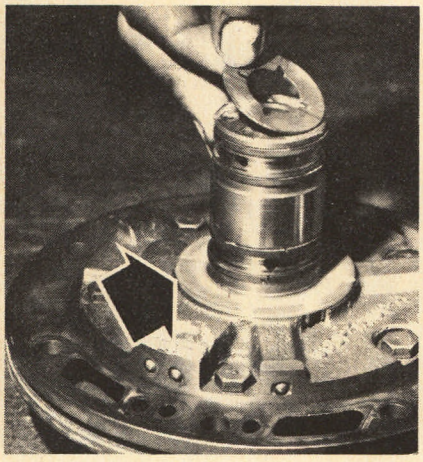
28. A No. 4 thrust washer is placed in back of front planet carrier, which is set on clutch assemblies. Now install input shell, shown, with sun gear and No. 5 thrust washer.



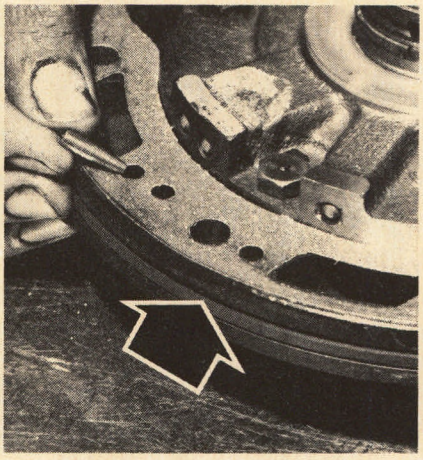
29. After installing a new front pump bushing in that unit, drop the front pump drive and driven gears in place. Use caution, and do not scratch or damage the pump gears.



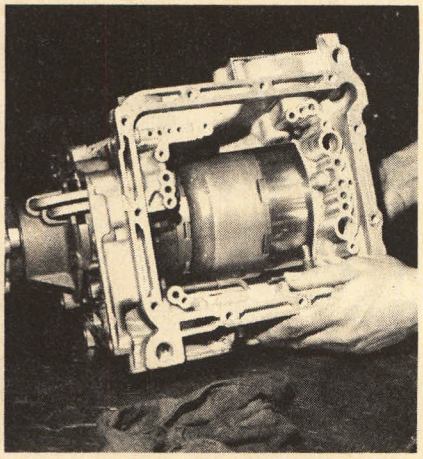
30. Install the four seal rings (arrows) on the stator support, then install stator into front pump. After attaching stator to front pump, check for free gear movement.



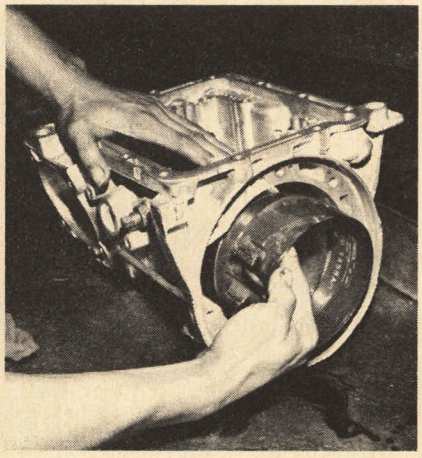
31. Install the selective thrust washer (arrow) on rear of stator, followed by installation of smaller selective thrust washer on end of stator shaft, being held by lube.



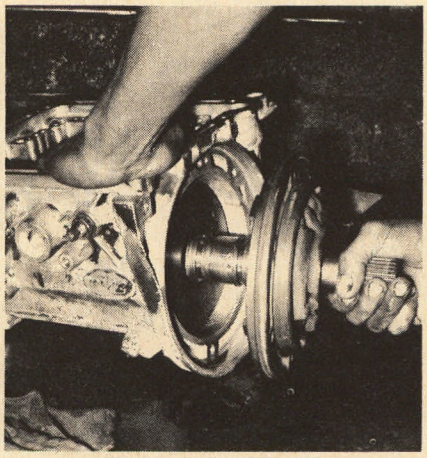
32. A large O-ring must be installed (arrow), then front pump gasket. A converter anti-ballooning valve is inserted in hole leading to converter. Dab of grease will hold it in place.



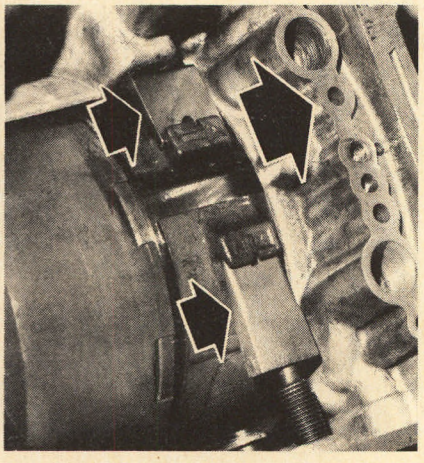
33. The complete clutch pack can now be installed through the front of the C-4 transmission case, with the input shell being fed in first. Unit is now nearing completion.



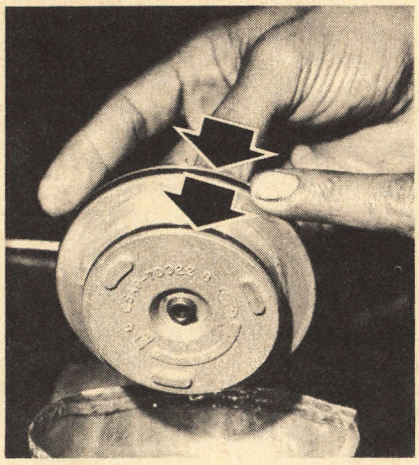
34. This operation is followed by installation of the intermediate band over the reverse-high drum. It would be wise to purchase a shop manual for more detailed instruction.



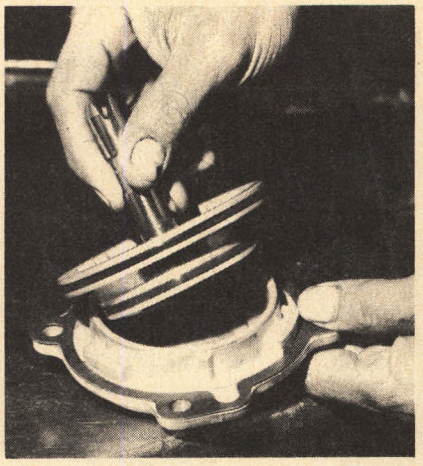
35. Stator and pump are installed in front case. Pump is held in place temporarily by two bolts until it is put in car. The input shaft is next slipped into the hollow stator.



36. Air hose is held against inlet (large arrow) and trans is tested at 40 psi air pressure to check for any leaks in clutch packs. Intermediate band struts are installed first.

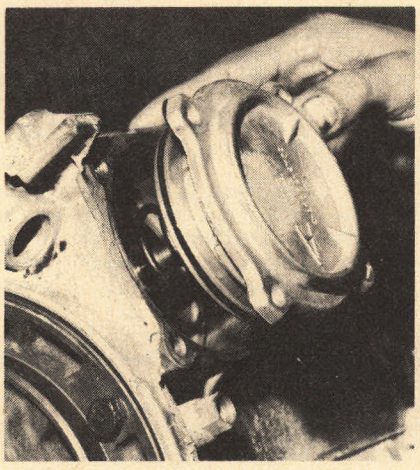


37. Two seals (see arrows) must be installed on the intermediate servo piston, then lubed with STP-type lubricant before installation. These lubing operations are very important.

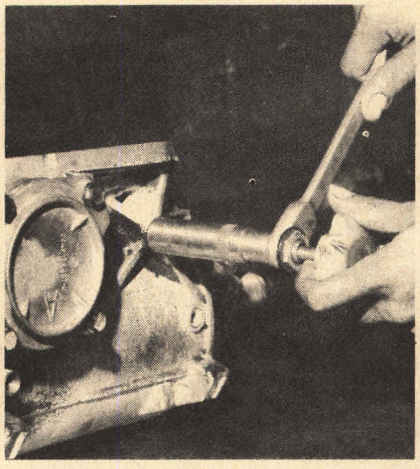


38. After lubrication, the intermediate servo piston can be inserted into its cover. All brand new seals and gaskets are used at Steve's when any automatic trans is rebuilt.

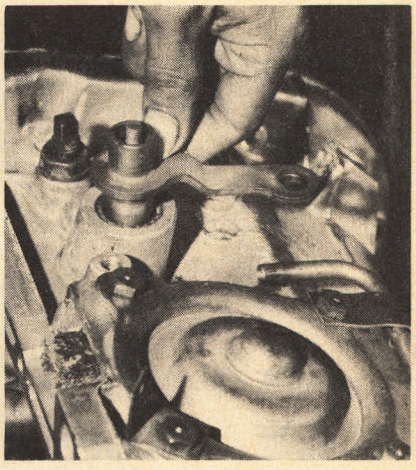
39. After installing the low-reverse servo piston return spring, lube the cavity with an STP-type lubricant. The piston seal is also lubed before it is installed in the case.



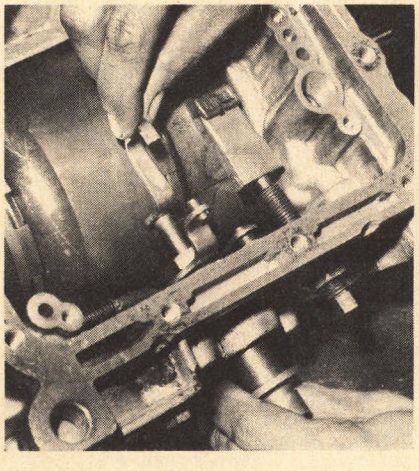
40. After lubing the walls of the servo cavity and installation of the servo piston return spring, install the servo piston and cover, with new gasket. Press cover down and bolt it.



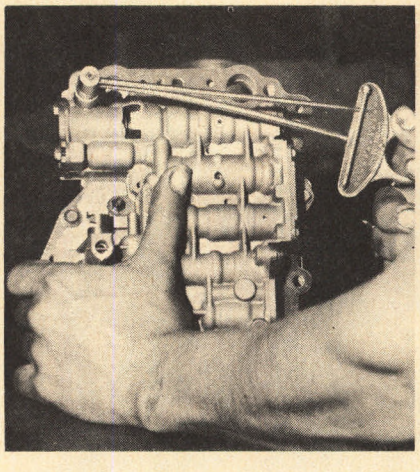
41. The reverse band can now be adjusted. The adjusting screw is then torqued to 10 in.-lbs., then the screw is backed off three full turns to arrive at proper final setting.



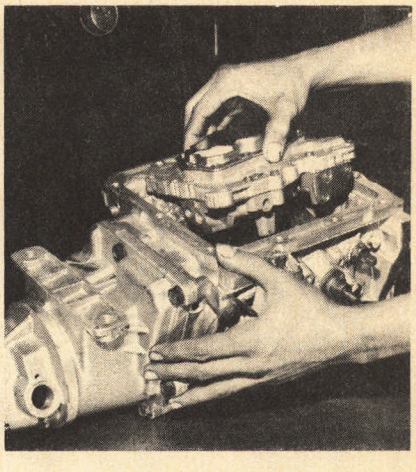
42. A new manual arm seal must be installed in the case after it has been disassembled. After this step, the manual arm for selecting reverse and forward gears can be connected.



43. The inner downshift lever can now be installed, followed by tightening of the nut on the manual arm shaft inside case. O-ring seal is installed on the outside portion of the case.



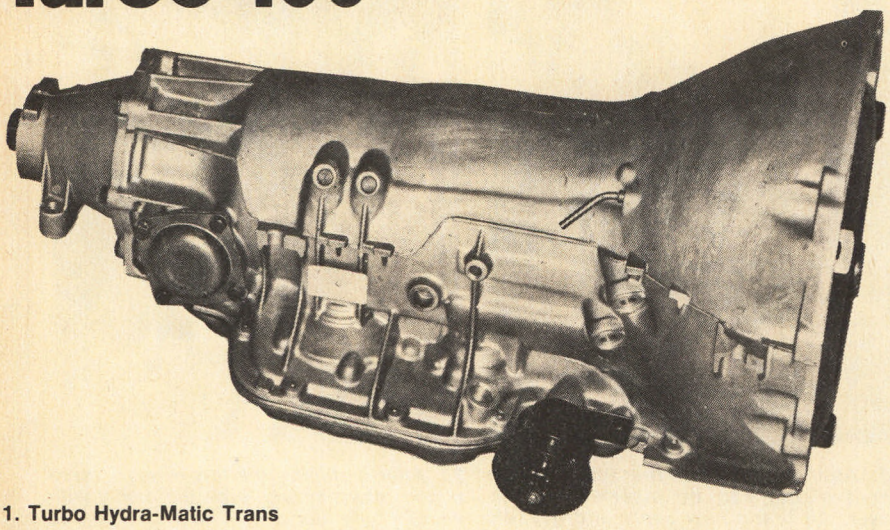
44. After assembling the valve body, the bolts should be torqued to 20-35-in.-lbs. The valve body filter should be torqued to 80-120 in.-lbs. of pressure. Follow these specs.



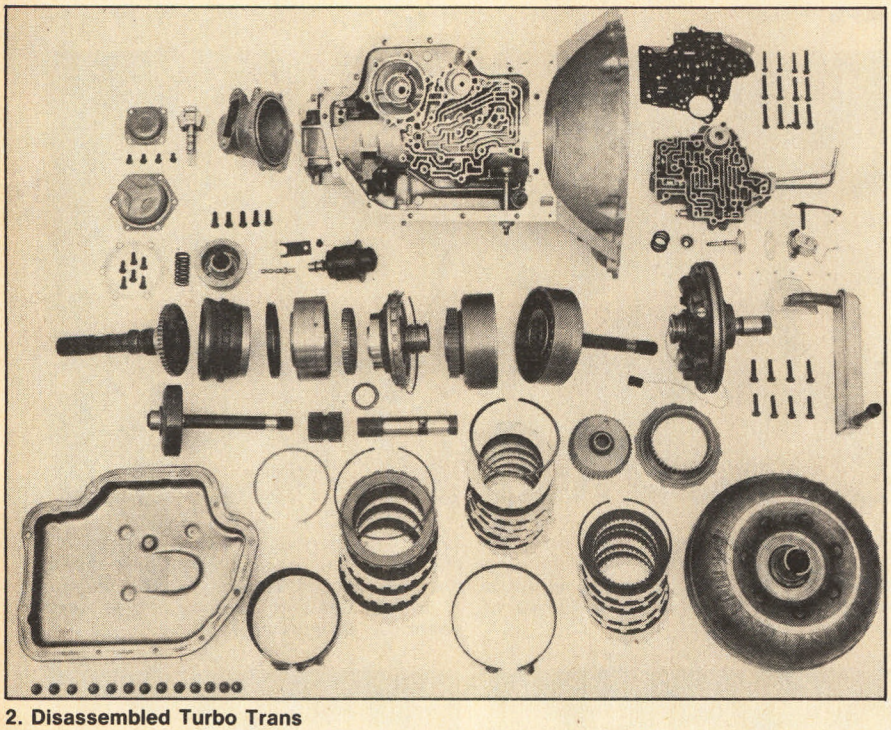
45. A new rear extension housing bushing should be driven into place, housing installed, followed by valve body installation. The final operation is that of installing the oil pan.

Automatic Transmission

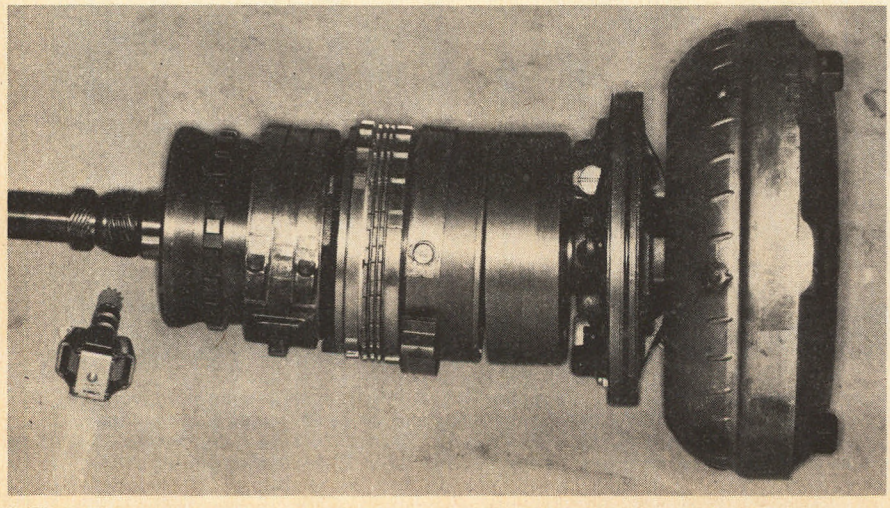
Turbo 400



1. Turbo Hydra-Matic Trans



2. Disassembled Turbo Trans



3. Turbo Drivetrain

Due to the great number of Turbo Hydra-Matic 400 automatic transmissions in service today, it was only appropriate that we should feature a transmission build-up article on this popular unit. The Turbo 400 is found in many of General Motors automobiles, and because many of these vehicles are now approaching 50,000-60,000 miles, the gearboxes are undoubtedly in need of rebuilding.

A visit to Steve's Transmission Service, 9012 Sepulveda Blvd., Sepulveda, California—a large, reputable automatic transmission establishment—permitted us to obtain these step-by-step assembly photos of a 400 going together. Use of this article in conjunction with a factory-prepared manual will permit anyone with a limited number of hand tools to assemble (and disassemble, by reversing the operations) his own Turbo 400 transmission. Scanning through the transmission section of our own shop manual revealed dozens of specialized tools recommended for use in installing seals, etc. Yet, we found during our picture taking session that very few special tools were actually required to complete this transmission.

An inch-pound torque wrench, sockets, a few end wrenches, snap ring pliers and screwdrivers were about all that were really needed, along with a bit of caution and care when it came to installing the seals and O-rings.

Most of us know someone who is a full-time mechanic, and if he isn't a transmission specialist he surely knows someone who is. These people may be able to help you out during assembly when it comes time to install the intermediate clutch piston snap ring, the direct clutch snap ring, or the forward clutch spring retaining snap ring, for example. They may not charge you a cent, thinking you're pretty trick if you have decided to tackle this transmission by yourself. If not, the damage to your wallet won't be that bad.

Too many people are afraid to tackle a job that appears as difficult or challenging as rebuilding an automatic transmission, but if you follow directions carefully, you can't go wrong. So, if you're mechanically inclined at all, and have the time and tools—along with the desire to do it yourself and save some bucks—then just follow the bouncing ball.

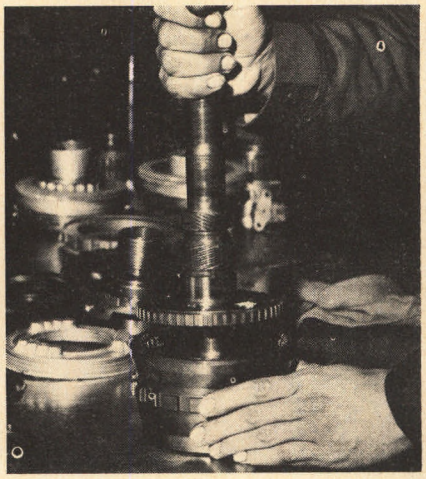
1. General Motors Turbo Hydra-Matic transmission is one of the best of the automatics available. A strong unit, it's also adaptable to racing.

2. There are many components in the Turbo 400, but with a little care, the right tools and following the directions, you can assemble one. Across the top we find the tail housing, main case, and valve body. Through the center are the many clutch housings and shafts with the front pump. At bottom are the pan, bands and clutches, converter.

3. Assembled, the Turbo gear train looks like this. The converter is at right. Drive clutches are hidden inside the clutch drums, with the bands outside. Front pump is located directly behind converter.

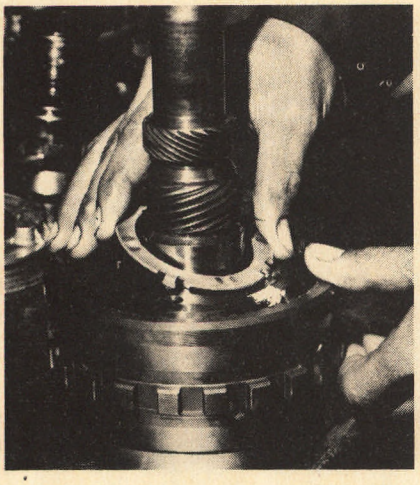
HOW-TO: Assembling a Turbo 400

1. Assembler Steve Bustamente installs rear internal gear to sun gear thrust bearing and two races on rear internal gear mainshaft.

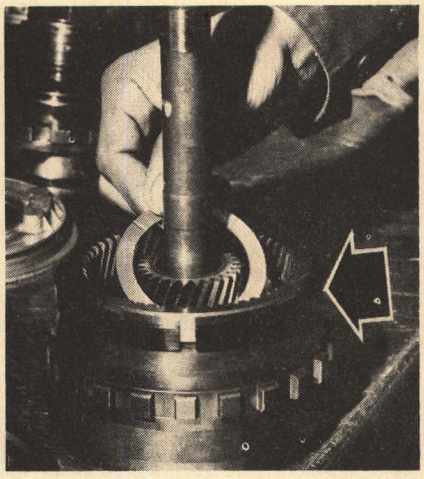


2. After dropping the rear internal gear mainshaft into output carrier, install the output shaft assembly into the output carrier, as shown.

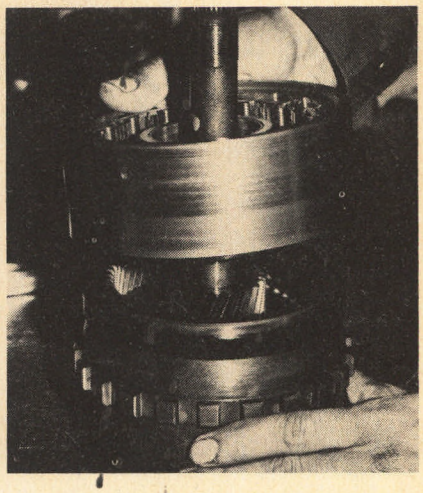
3. The output-shaft-to-carrier snap ring can now be installed. A steel speedometer gear has already been put in place on the output shaft.



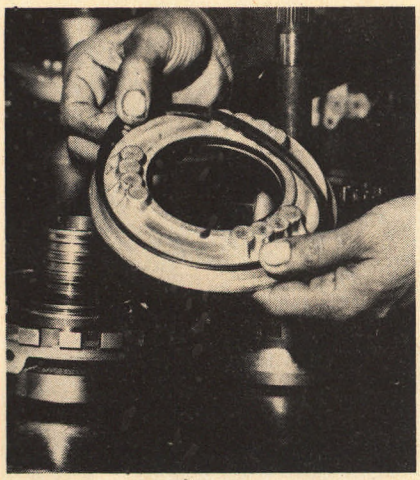
4. Before installing the output shaft to the case thrust washer, Steve adds a dab of grease to hold it. Retaining tabs are locked in pockets.



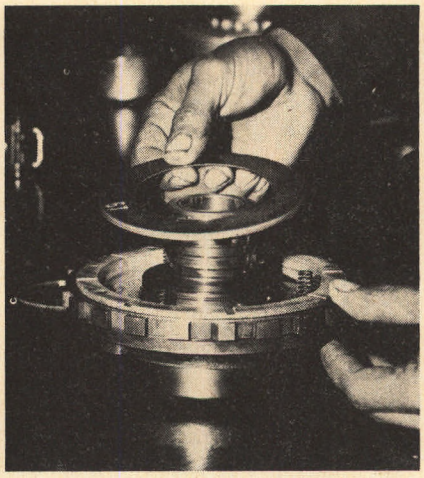
5. A composition ring (arrow) is slipped about output carrier to hold noise down. Another thrust washer is added prior to the reaction carrier.



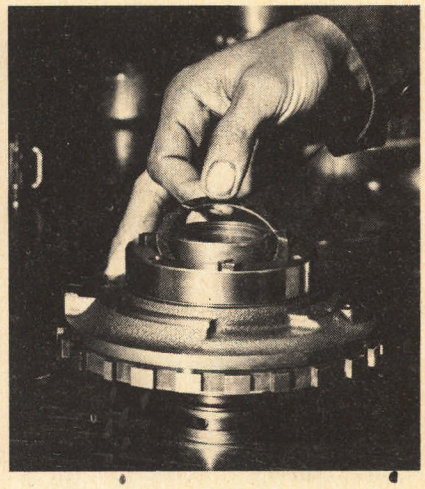
6. With the sun gear in place, the roller clutch cage and rollers are installed in the reaction carrier, which is then placed on output unit.



7. The intermediate clutch piston inner and outer seals are put in place, then the unit is set into the main center support assembly.

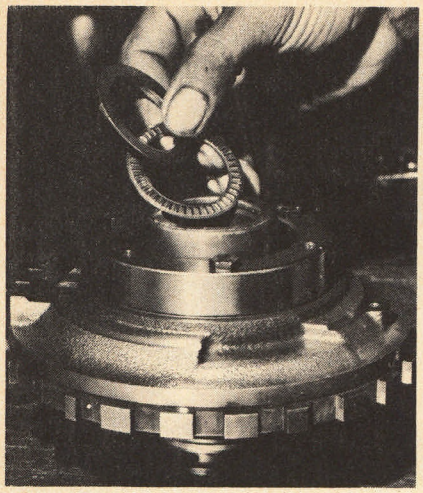


8. The intermediate clutch release springs are installed, then the intermediate clutch spring retainer is installed, held by a snap ring.

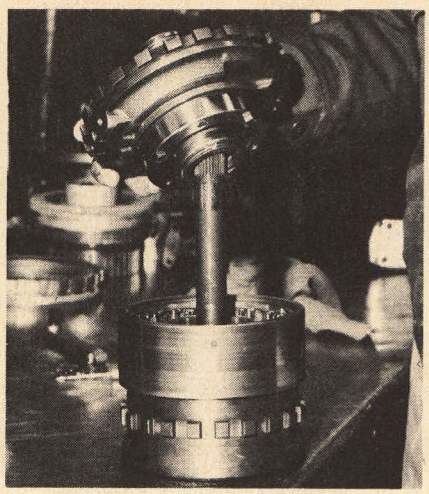


9. Center support assembly is turned over, and its thrust washer is then set in place. Clutch piston should be air checked with compressed air.

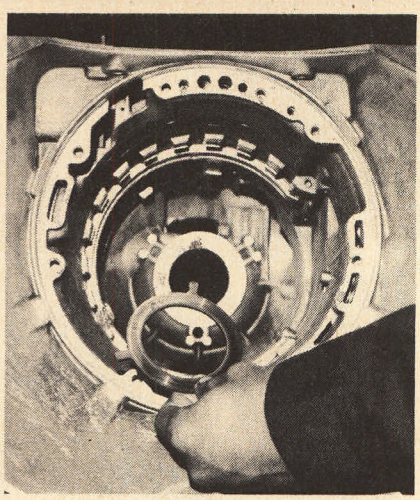
HOW-TO: Assembling a Turbo 400



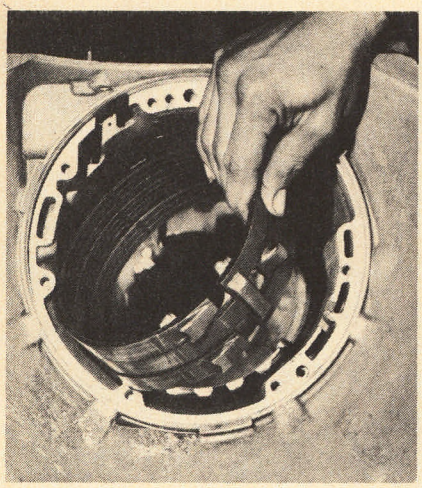
10. Grease is dabbed on the needle bearing and thrust washer before it's installed on end of center support. Support to case spacer is now added.



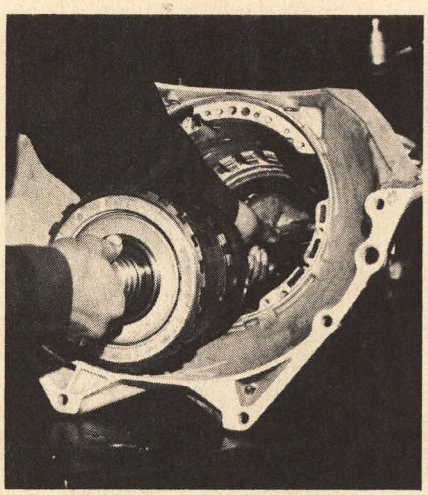
11. The center support assembly is next installed into the roller clutch in the reaction carrier. Be sure to check rotation of center support.



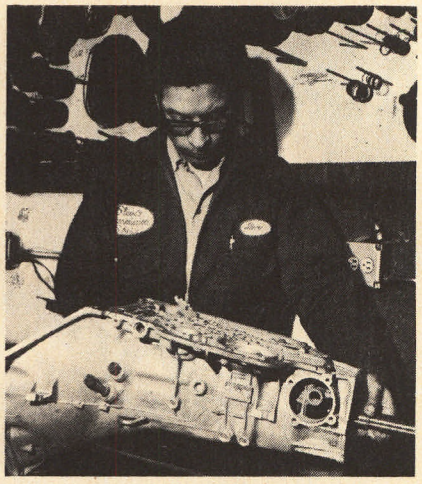
12. Install the rear unit selective washer into slots provided inside rear of trans case. Proper washer was determined by end-play check.



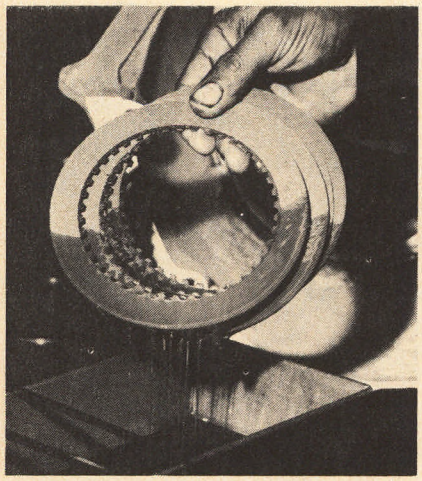
13. Install rear band assembly so that the two lugs index with the two anchor pins. Check to make sure that band is seated on the lugs.



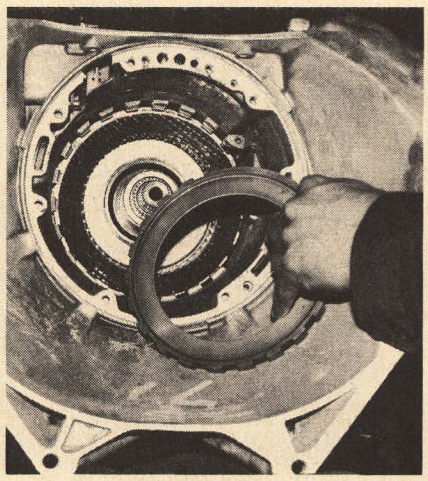
14. Install proper rear selective washer into slots provided inside rear of case, then install complete gear unit assembly into the case.



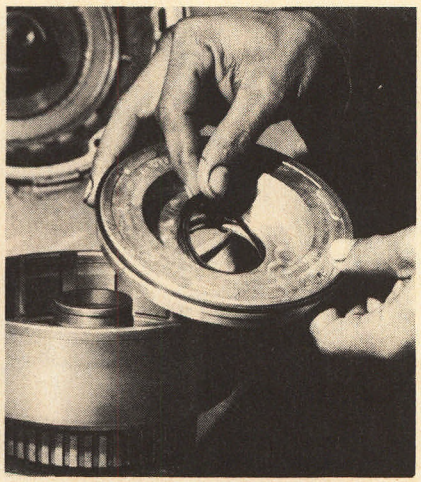
15. Steve aligns application hole on center support with case application hole. Then he installed a screw for the intermediate clutch apply.



16. Center support to case spacer and snap ring are installed, then intermediate clutches are soaked in ATF before being installed in case.

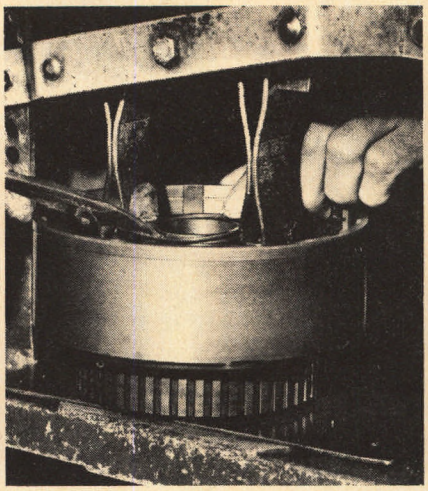


17. After installation of the three steel and three composition clutch discs, alternated, the intermediate backing plate is installed next.

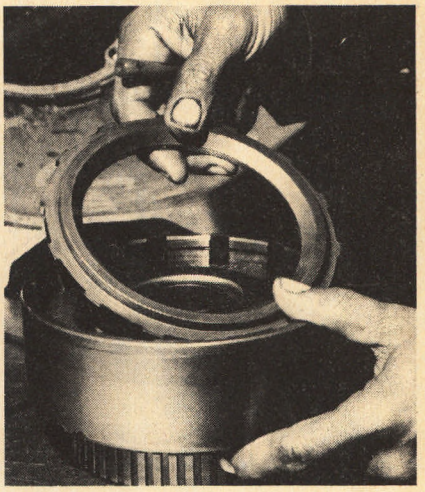


18. The direct clutch piston outer seal is already installed, and now inner seal is being inserted in the piston. Seals are both lubed.

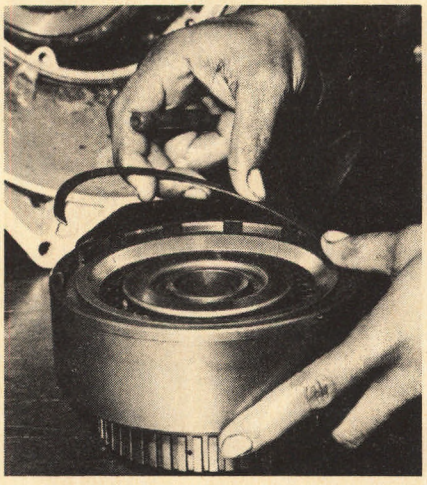
19. Direct clutch piston is placed into the forward clutch housing, then 16 clutch release springs are set into pockets about the piston.



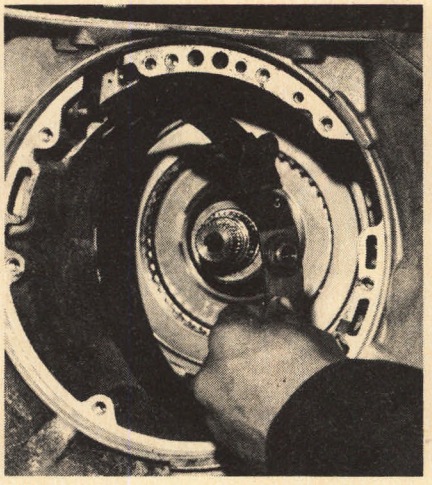
20. Steve's uses spring compressor to compress the clutch release springs after a retainer plate is installed. Now install a snap ring.



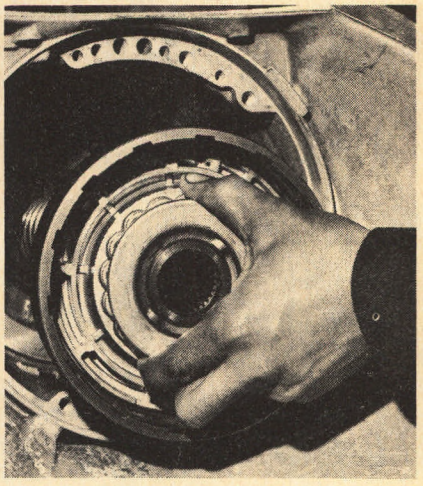
21. The direct clutch backing plate can now be installed in the direct clutch housing, preceded by wavy steel, flat steel and clutch plates.



22. The backing plate snap ring can now be installed in the direct clutch housing. Small screwdriver will assist in getting it in groove.

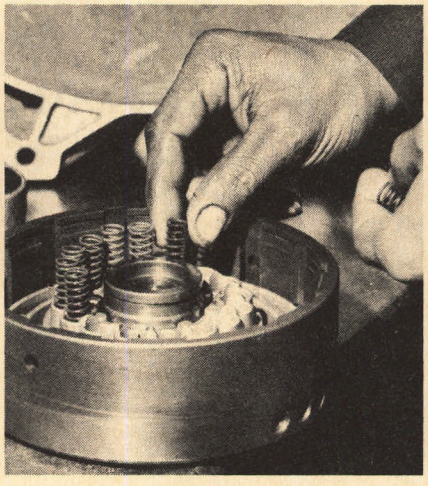


23. Moving back to the transmission, install the front band with anchor hole placed over band anchor pin and apply lug facing servo hole.

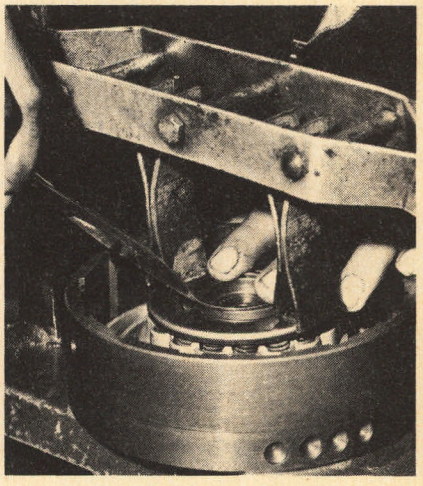


24. The direct clutch drum is now installed in turbo case without the clutch plates (being installed in photos 21, 22); it's easier empty.

25. Steve rotates forward clutch piston as he installs it in the forward clutch housing. A .006-in. feeler gauge helps slide seal down.

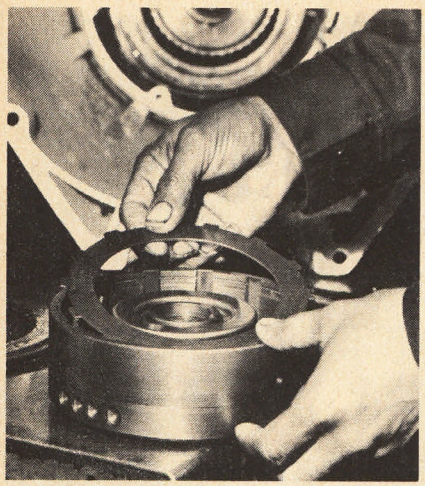


26. Sixteen clutch release springs (green) are installed in pockets of forward clutch piston. Always lube seals during assembly; use caution.

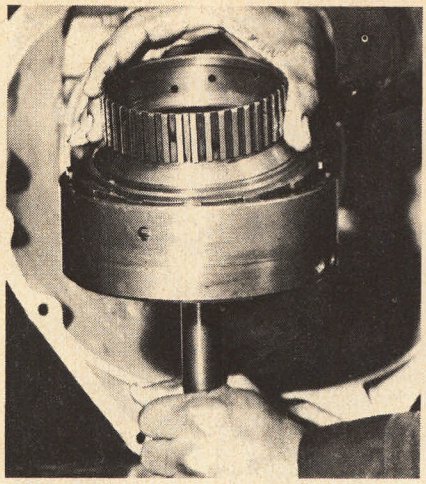


27. Place forward clutch assembly in press, install retainer ring and snap ring. Job can be performed without a big spring compressor.

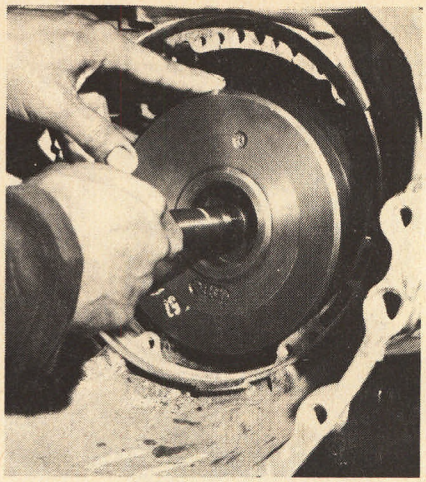
HOW-TO: Assembling a Turbo 400



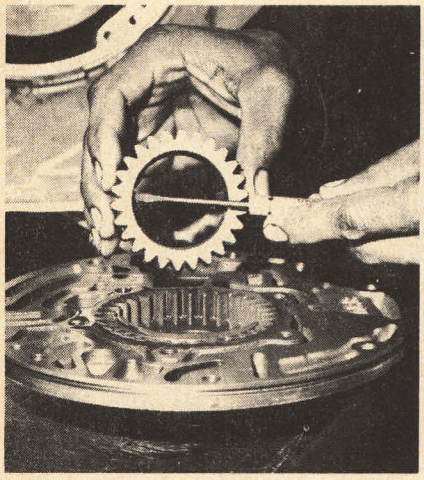
28. Waved steel plate, then the composition and flat steel plates, alternated, are dipped in fluid then installed in forward clutch housing.



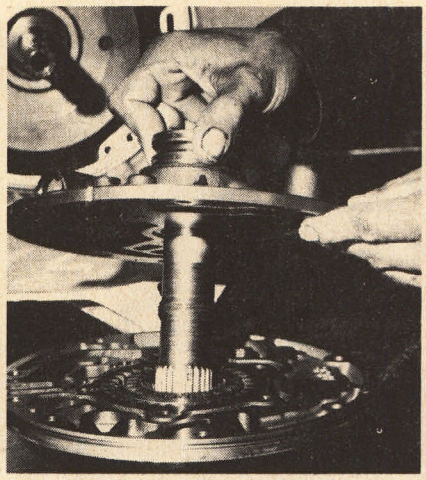
29. Forward clutch hub and thrust washers are installed, followed by direct clutch hub and snap ring. Turbine shaft is on clutch housing.



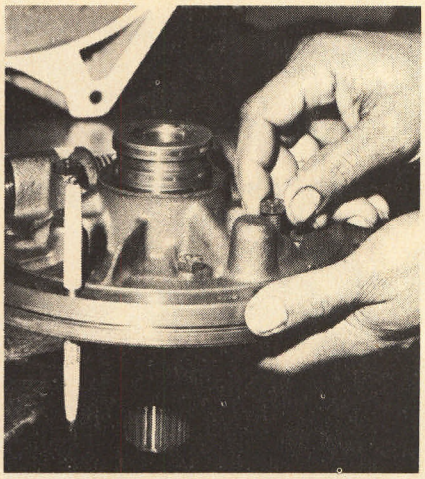
30. Grasp turbine shaft and slide forward clutch drum assembly into direct clutch drum. Direct clutch hub will move right into the drum.



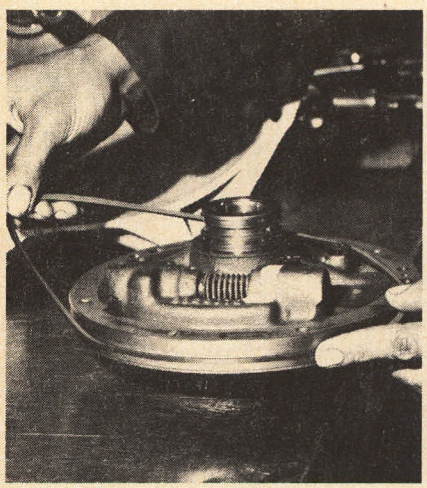
31. Front pump body with driven gear is ready for drive gear. Oil teeth before installing gear. Make sure tangs are installed on the top side.



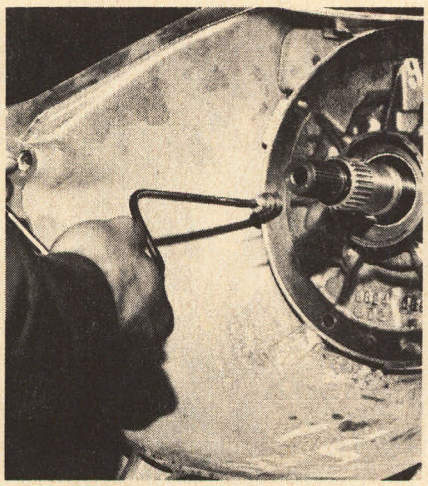
32. Pump cover can now be installed onto pump body. Hole in bench top accepts shafts of different parts, making work on trans quite easy.



33. A pair of ballpoint pens may be used to index bolt holes; then it's easier to install fasteners. Tighten pump cover bolts to 15 ft.-lbs.

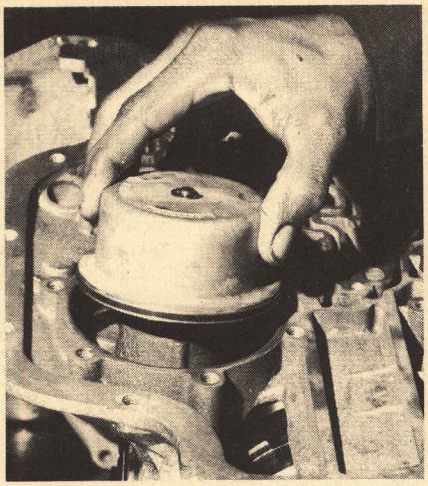


34. Install front pump gasket, then the O-ring seal. Lube seal with STP-type lube; carefully install front pump assembly on trans case.



35. Front pump is secured to case, then end-play is checked with dial indicator. Should be from .003-in. to .024-in. Install new pump seal.

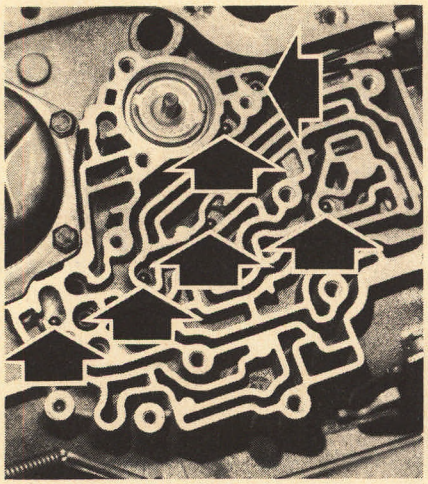
36. At this juncture, the case to center support bolt is installed. Hollow bolt is used as oil passage for intermediate clutch apply.



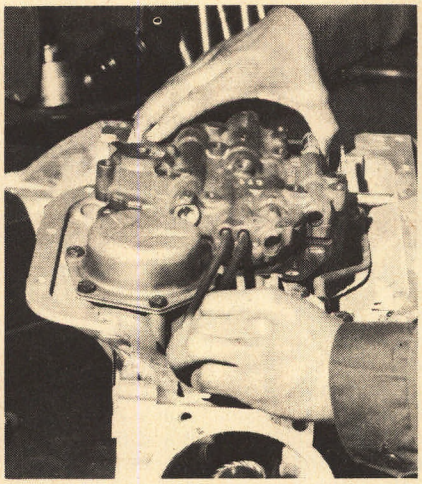
37. New O-ring is installed on rear servo piston, which is lubed. Then rear accumulator spring is dropped in place, followed by the piston.

38. Metal rear servo gasket is next installed, then rear servo cover is bolted down. Torque all the attaching screws to 15-20 ft.-lbs.

39. The front servo piston can now be installed in case, adjacent to rear servo. Care should be taken to make sure components are clean.

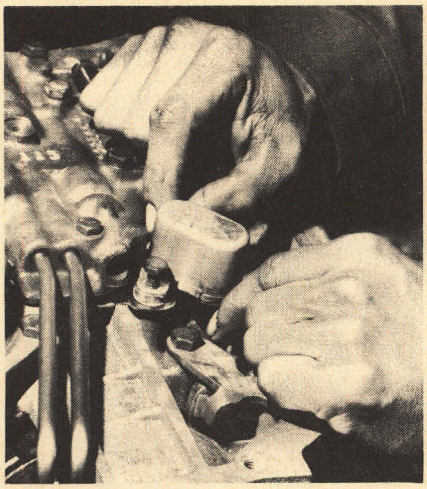


40. Arrows depict six check balls that must be installed in pockets. Now install valve body spacer plate and gasket; gasket next to trans.

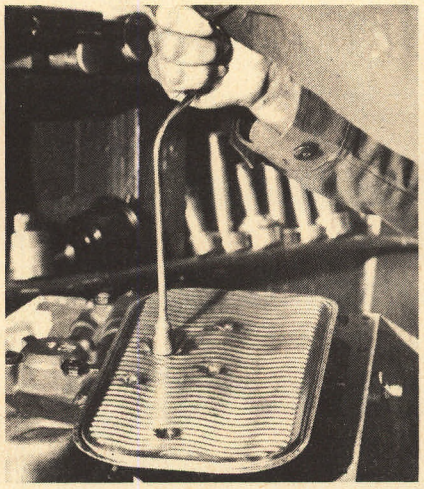


41. Valve body can now be installed. Make sure manual valve is properly indexed with pin on manual detent lever and governor pipes are in.

42. Guide pins or screwdriver may be used to align valve body so that screws can be installed. Now install manual detent roller spring assembly.



43. Make sure lead wire clip is installed (except P model), then tighten solenoid, valve body bolts. Install filter intake pipe, O-ring.



44. Use new filter, make sure it's properly installed on intake pipe. Never wash old filter, but replace it. Install new bottom pan gasket.

45. Install bottom pan, torque pan bolts to 15 ft.-lbs. Then, finally, install governor assembly and rear tail housing onto trans case.

Driveshaft & U-Joints

If you've ever wondered why your car has to have a driveshaft, the answer is it doesn't. Most of the motorcycles around use chains to accomplish the same purpose, and their owners wonder why anybody uses a driveshaft.

Chain drive on automobiles went out with button shoes, which must have been an awfully long time ago. Most American passenger cars use a single-piece driveshaft with a U-joint at each end. U-joints allow power to be transmitted through the various angles that the rear end causes as it goes up and down and travels over the road. Working in conjunction with the U-joints is a slip-joint on the back of the transmission, which allows the driveshaft to move in and out. This is necessary because the movement of the rear end actually shortens and lengthens the distance between the rear end and the transmission whenever the rear end goes over a bump.

That's about all there is to a driveline. Ordinarily nothing would ever go wrong here except for possible replacement of the U-joints. Some cars have grease fittings, and you're supposed to lubricate the U-joints when you lube the chassis. In the course of hard driving you occasionally hear of someone breaking a driveshaft or U-joint, but normally U-joints just wear out. You can tell when they're worn and loose by a "clunk" sound when you put the car in gear. Improper rear-end gear lash can also make this type of sound so you'll need to put the car on a lift to check it out.

We have two general types of drive systems on American passenger cars. One is the "torque-tube" drive. Here, the driveshaft is enclosed inside a large tube that bolts solidly to the rear axle. The tube pivots on a large ball joint on the back of the transmission, and there is a U-joint inside this ball. There is no joint at the back of the driveshaft. The large outside torque tube absorbs torque and drive forces on the rear axle, with radius rods of some kind to keep the axle in line. Cars using torque-tube drive include early Ford products up through 1948, Chevrolets through '54, and Ramblers and big Buicks up to the early 1960's. Torque-tube drive has fallen out of popularity on late cars because the tube telegraphs too much road vibration to the passenger compartment of the car.

All other cars use an open driveshaft with U-joints at each end and a slip joint at the front. The shaft has to transmit only engine power, not take rear axle forces and twisting. These forces are taken either by long leaf springs, as on late Chrysler products, or by trailing suspension arms on late GM and Ford lines that use coil springs.

The principle in coil or leaf spring designs, is really the same. The driveline only has to transmit power, and rear-end drive forces are absorbed either by leaf springs or suspension arms and cross links.

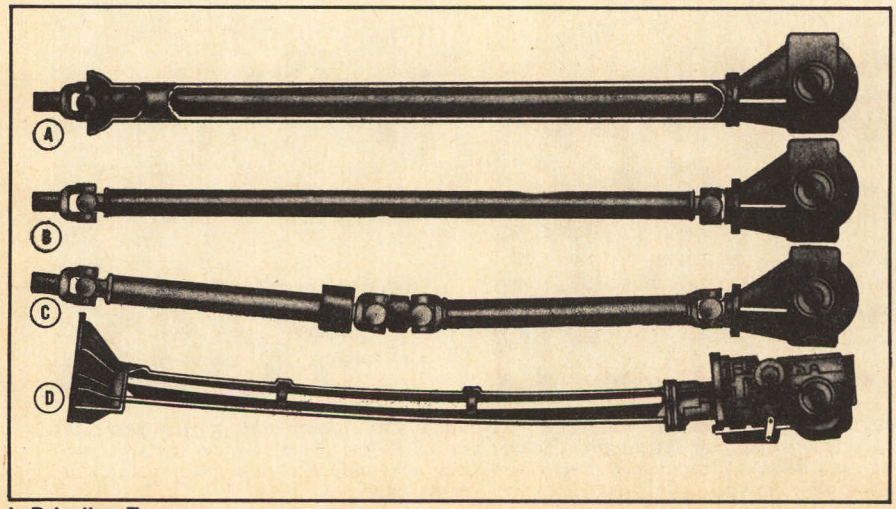
It should be mentioned here that a number of General Motors cars (including Chevrolet) used *2-piece* driveshafts with X-type frames in the late 1950's and early 1960's. These had a support bearing near the center of the shaft, in the center of the X-frame, with a short section of driveshaft in front and behind the center bearing. There were three U-joints. Servicing this type of driveline is a little more work, but the operations are essentially the same as for various other designs.

SETTING UP THE DRIVESHAFT

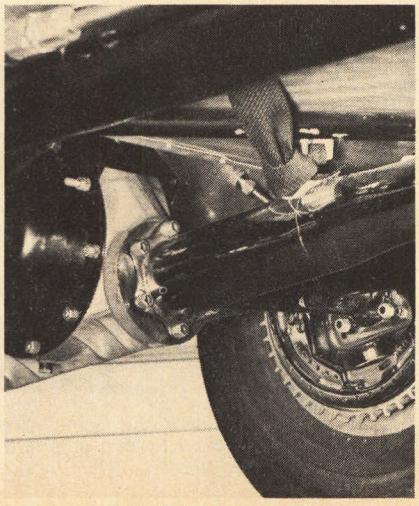
Driveshaft vibration is a chief cause of roughness and rumble in passenger cars, and companies spend a lot of effort in engineering and testing to get rid of it. They also carefully balance driveshafts on all cars on the assembly line, and adjust U-joint angles and phasing, to control the problem in production, and *you* can mess everything up in a few minutes when you start tearing into a driveshaft and U-joints—if you do not know what you're doing.

In the first place, when removing the driveshaft you should make sure that you will get all elements back in the same position or "phasing" they originally held. U-joint yokes, for instance, should be in the same rotational position on the shaft as they were. This can be easily done by merely marking the shaft and yoke before disassembly. (Usually, there are phasing marks from the factory, but these are sometimes hard to find.) Note that most shafts have their U-joints phased so yokes at the front and rear of the shaft are at 90° to each other. If you should forget to mark, or can't find the factory marks, do it this way as a rule of thumb. But the safest thing is just to remember to mark the shaft and joints when they are removed, and then they can be bolted right back together in that relationship.

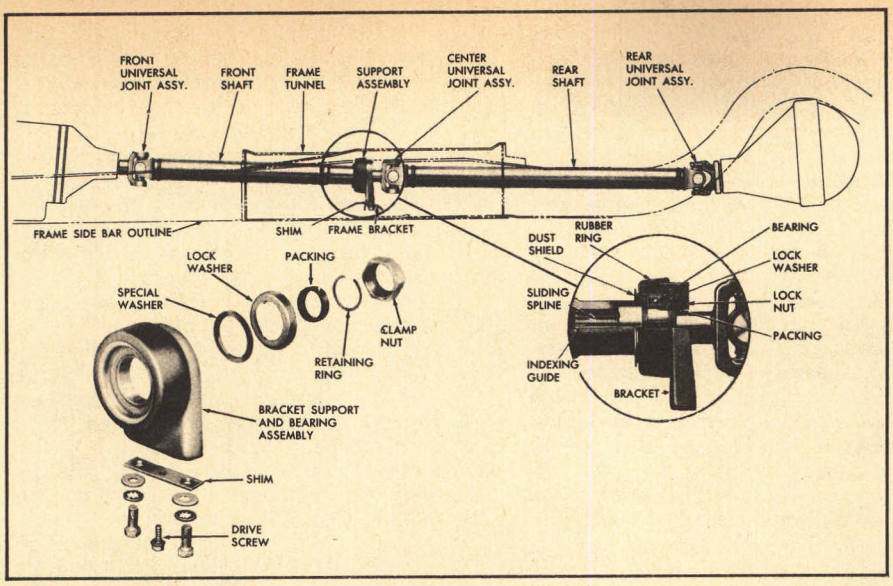
Driveshaft or U-joint *angles* are also critical. A little thought will show why. When a U-joint is transmitting power through an angle, the yokes have to flex back and forth at high speed as the shaft turns. The rotational motion they deliver is not an even rotation, but a kind of pulsing motion that speeds up and slows down twice each revolution. The greater the angle through which the power is transmitted, the more uneven this pulsing delivery and the more vibration. The easiest answer is just to see



1. Driveline Types



2. Torque Tube Drive



3. Two-piece Driveshaft

1 The basic driveline types: (A) Torque tube, (B) One-piece open driveshaft, (C) Two-piece open driveshaft, (D) One-piece curved driveshaft without universal joints.

2. Torque tube drive was formerly used on several makes of cars. The tube containing the driveshaft is rigidly attached to the differential housing and absorbs driveline reaction torque.

3. Two-piece driveshafts were used at one time on several U.S. cars, including Chevrolets. Shorter unsupported driveshaft length added complexity, reduced vibration.

4. At the front of a torque tube drive is the "torque ball," an enclosed housing containing the universal joint.

that the driveshaft angles are kept as straight as possible, so the U-joints don't have to flex very much as they turn. The ideal driveline would have zero angles in the U-joints. But, of course, this is impossible with the rear axle bouncing up and down.

Each different car maker has certain recommendations for maximum and minimum U-joint angles. Space won't permit covering all of these, but you can find them in the shop manual for that model at your car dealer. As a rule of thumb, just keep the angles very small with a normal load in the car—like 1° or 2°, and with 3° to 4° as maximum. This is the angle between the axis (centerline) of the driveshaft and the axis of the U-joint yoke at the front and rear end. About the only way you can measure it accurately is with a bubble protractor. This has a long flat flange on one side, to lay against the shaft or yoke housing, with a rotating bubble wheel in the center that will show angles very accurately. One of these instruments is expensive, but a garage may have one.

In most cases, the factory recommendation for setting driveshaft angle involves changing the angle of the rear joint so it exactly matches up with whatever angle the front joint has. When both angles are the same on a 1-piece driveshaft, the U-joints work together instead of fighting each other. When there are leaf springs supporting the rear axle, the rear U-joint angle—sometimes called the pinion angle—can be easily changed by putting wedge-shaped shims between the spring and its seat on the housing.

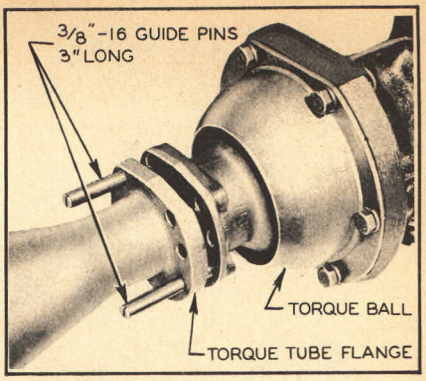
On Ford and GM models using coil springs and trailing suspension arms it's usually necessary to shim either at the front pivot of the suspension arm or where the rear axle pivots on the arm. Your shop manual will tell all about it. All you're doing, in effect, is to tip the rear axle nose a little to change the angle between the rear U-joint yoke and the driveshaft.

REMOVING THE DRIVESHAFT

Most cars have a plain open driveshaft with a U-joint at each end and slip joint at the front, either ahead of or behind the front U-joint. Study the design of a typical U-joint and you will see that there are two Y-shaped yokes with a cross-arm piece that connects them, usually with needle bearings where the cross-arm revolves in the yokes. (The cross piece is called the "trunnion.") Most cars use this type of trunnion-type joint.

In this case, the rear U-joint on the driveshaft will be made so the bearing bosses on the rear yoke are split, enabling the joint to be quickly taken apart. The trunnion bearings will be secured to the yoke by simple U-bolts or some kind of little casting with cap screws, or maybe just a strap of steel with clamps or bolts. This design is necessary in order to get the driveshaft out of the car. In other words, you just split the rear yoke bearing retainer (whatever the design), and the U-joint will come right apart and the driveshaft will drop down at the rear. Be careful that you don't drop the trunnion and needle bearings and damage them. The needle bearings should be taped to protect them in storage, until reassembly. Note that the rear half of the split rear yoke is attached directly to the rear axle input shaft. This is called the "companion flange." You won't be doing anything with this in normal U-joint service, unless it's broken.

After the rear U-joint is split and the back of the driveshaft is dropped, the



4. Buick Torque Ball

shaft can be removed by merely pulling it back until the splines in the front slip joint slide apart. This distance might be 2 or 3 ins.

Getting the driveshaft out of a torque-tube car is more of a job. On Fords and Buicks, for instance, you have to loosen the whole rear axle assembly and move it back a little in order to get the ball joint at the front of the torque tube apart. It's simple to unbolt the ball retainer from the rear of the transmission. When taking the ball assembly apart, be careful not to lose the seals and O-rings that retain the lubricant (though these should be replaced with new parts before reassembly). It's much simpler on a pre-'55 Chevrolet with torque-tube drive. Here you just unhook the hand brake brackets and cables from the drive tube, remove the cap screws that hold the ball-retainer collar to the back of the transmission and slide it back on the driveshaft housing (or torque tube). Next remove the cap screws that hold the trunnion bearings to the front yoke. Place a jack under the driveshaft to keep it from dropping, and carefully remove the two front-yoke trunnion bearings. Then the driveshaft torque-tube assembly can be lowered—and the rear yoke of the U-joint will slide right off the shaft splines.

Keep in mind that you rarely have to remove the complete driveshaft from a torque-tube-drive car. Usually, if there's anything wrong, it's the front U-joint or ball joint around it (there isn't any U-joint in the back). So your driveshaft removal job is usually just a matter of removing the front ball-joint retainer from the back of the transmission, and dropping the shaft down to get to the U-joint.

Installing a driveshaft is pretty much the reverse of the above. The toughest part is holding the shaft up while you connect the U-joint. When reinstalling a torque-tube drive, especially where you have replaced the oil seals and O-rings, the ball joint might be too tight in its socket for easy movement of the axle up and down. On pre-'55 Chevrolets this adjustment of the ball tension is made by adding or subtracting shims under the cap screws that hold the ball-retainer to the transmission. With the screws tightened you should be able to move the ball with hand pressure on the tube. If too tight, add shims and check again.

SERVICING U-JOINTS

In late years, the car manufacturers haven't been recommending any regular

service work on U-joints other than periodic lubrication through a grease fitting. But a few years ago they used to suggest taking them apart, cleaning, and lubricating every 2 years. If you might want to do this on your car, you will need some information on assembly and disassembly.

On a conventional trunnion-type joint, as we mentioned, you have needle bearings on each end of the trunnion where it pivots in the two yokes. It's a bit of a trick to get these bearings out and the joint apart. You will note that the bearing cups are retained in the outer ends of the yokes by C-shaped clip rings in a groove. On many models the clips are on the inside of the yoke, so you will have to tap them out with a punch and hammer. Then there are the designs without any clips at all. The cups are held in place by plastic injected through a hole in the yoke. You can disassemble these joints, because the plastic will shear when you hammer or press the cups out. But you can't use the same cups and trunnion again. You must get a replacement kit that comes with the clips and grooved cups.

After you are sure that there are no clips, or have removed the clips, set the joint up in a vise or on a support of some kind that will be open below the bearing hole in one end of the yoke (there are four of these ends in all). Then take a punch and gently tap the *opposite* bearing cup *inward* with a hammer. This will push the trunnion through the yoke far enough so the bearing cup will drop out of the other end. You have to repeat this the other way, then on the two bearings on the other yoke.

Another approach is to use a punch and tap on the center of the trunnion (at the cross) until the bearings drop out. Just tap easy, not too hard. Be careful not to damage the bearing bores in the yokes or the surface on the trunnion. And it's a good idea to cover the bearing cups with tape to prevent damaging them until reassembly is completed.

Servicing this conventional trunnion-yoke joint is very simple. First clean everything carefully with solvent, including the grooves for seals and rings, then inspect everything. There shouldn't be any excessive wear in the yoke bores or on the bearing surfaces on the ends of the trunnion arms. The needle bearings should look good, with no looseness in their cups and no obvious wear, galling, or broken needles.

After everything is clean and ready for reassembly, put a small amount of chassis grease in the bearing cup. This will be retained by the seal and retainer, and you should have adequate lubrication for at least 2 years; or, as they say, "for the life of the car," on late models.

1. Assembly of bearings to the trunnion. Examine each bearing and bushing carefully, replace if required. Keep it clean!

2. The normal "one-piece" driveshaft, showing two U-joints and slip joint.

Now you're ready to reassemble. This procedure is pretty much the reverse of what you've done. Modern U-joints have seal and retainer rings on the inner ends of the bearing cups, that go between the cup and a shoulder on the trunnion arm. These will have to be assembled before the bearing cup. A standard procedure is just to put the seal and retainer rings on the trunnion, then tap the bearing cups into the yoke bores part way, alternating each end so the trunnion journal can be slipped up inside the bearing. You can readily see the easiest way with your particular joint design. Just be very careful when tapping these bearings into place that nothing gets damaged. It's a ticklish job. Also be sure the little C-shaped clip rings are snug in their grooves. If one of these were to break or slip out you'd have big trouble.

The U-joints in the front end of torque-tube drives are generally of this trunnion-type, with minor variations, so the servicing procedure would be about the same as above.

The unique "ball-and-trunnion" joints used on one or both ends of most Chrysler products of the 1950's (Plymouth, Dodge, etc.) are another deal entirely. These are designed to combine the flexing of a conventional U-joint with the in-and-out motion of the slip joint. There is a round boss on the front end of the driveshaft with a hole in it and a pin pressed through it. Needle bearings and balls are on the outer ends of the pin, and these ride in round slots in a large collar that bolts to the transmission output shaft. In this way we get the necessary flexing and plunging motion by the balls rolling in the slots.

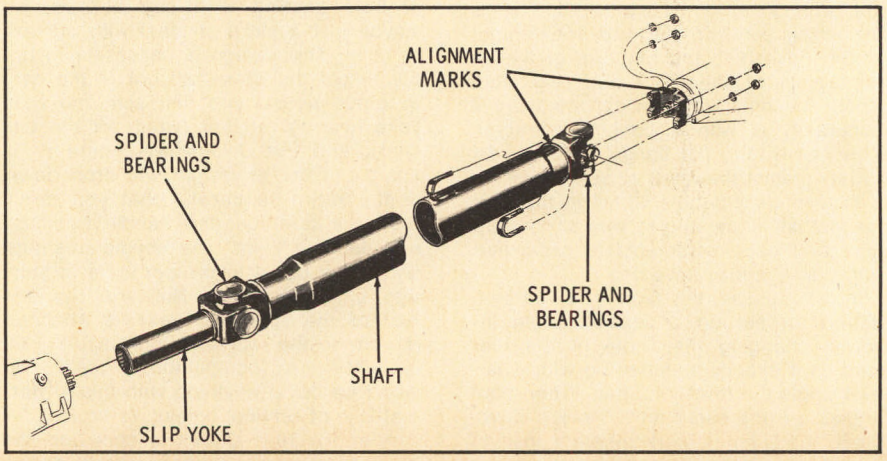
Servicing is quite simple. The driveshaft is dropped by splitting the rear conventional U-joint. To withdraw the driveshaft from the front, you have to detach the ring clips that hold the rubber boot, and then the shaft will pull right out of the collar (or body) with the pin and rollers intact. Inspect all parts for wear and clean everything carefully (including the inside of the collar and slots) with solvent. Do not press the pin out of the driveshaft boss unless it is loose. This pin has to be pressed in very accurately, within .006-in. on each side, or you're apt to get driveline vibration. It's rarely necessary to replace a pin. If the rollers, needles or centering buttons are worn they can easily be replaced. When assembling, repack the body or collar with 1¼ oz. of chassis grease, and put the joint back together, following the disassembly procedure in reverse.

A word about servicing the U-joints on Chevrolets of the 1960 era that had the 2-piece driveshaft: To remove the complete driveshaft, you need to remove the bolts that hold the center support bearing to the X-frame, then split the rear U-joint in the usual way to drop the back of the driveshaft. Then the whole shaft assembly can be withdrawn from the front slip joint. The center bearing and support remains on the front shaft.

To remove the center U-joint, take out the large bolt that holds the joint yoke to the front driveshaft; then disassemble the joints in the usual way, as they are of the conventional trunnion-yoke type. It's recommended that you *do not* try to remove the support bearing or bracket. It rarely needs attention, and it's very easy to damage either the bearing or the shaft in pressing it off. Special tools are needed to remove it. Take this job to a Chevrolet garage.

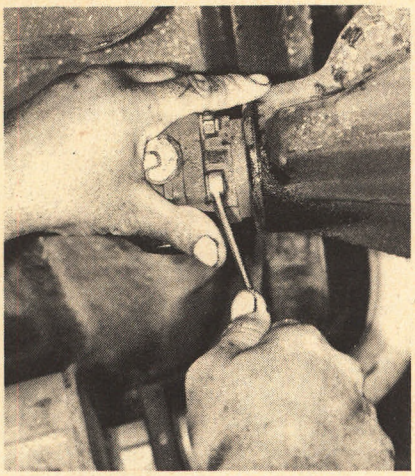
Some cars have constant-velocity joints. They look like a double U-joint with a heavy connecting double yoke. Before disassembly, mark all three yokes with aligned punch marks. They come apart about the same as a regular joint, except that there's a bunch of parts hidden behind the center yoke (a ball and socket arrangement) that keeps the two parts of the joint in line. Watch carefully when you disassemble it so you can get the pieces back together right. During reassembly, line up the punch marks you made before so the joint will keep its original phasing.

1. Trunnion Assembly

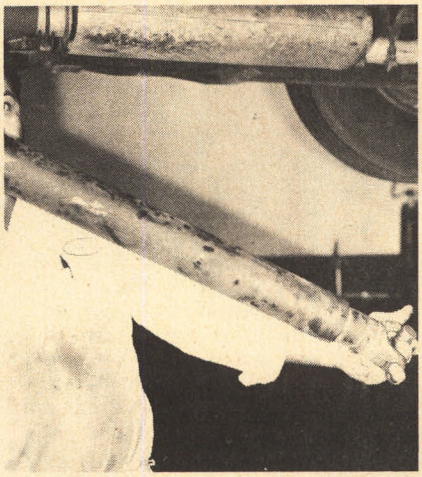


2. One-piece Driveshaft

HOW-TO: Repacking a U-Joint

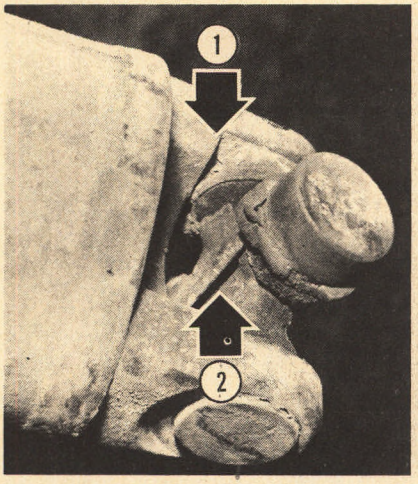


1. To repack U-joints that do not have grease fittings, unbolt both sides of the U-joint from the companion flange on the differential.



2. Drop the end of the driveshaft from the companion flange. Lower it as shown then pull it rearward until slip yoke comes free of transmission.

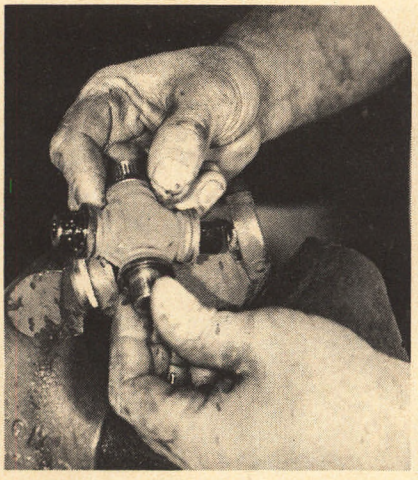
3. Clamp the shaft securely in a vise and with a pair of pliers, remove each of the retaining clips. Needle-nose pliers work best on these spring clips.



4. Some types of U-joints have retaining clips on the inside (1). Note the strap (2) that holds cups in place when removing shaft from the car.

5. Use a screwdriver to carefully pry the two free bearing cups before removing the U-joint cross from the shaft. They could fall off and be damaged.

6. There are special tools for this job, but a hammer and a punch will do it just as well. Apply enough force on the flange to free the cross.



7. Once the cross has been worked free, remove the other two bearing cups. Pry them loose with a screwdriver as you did the first pair.

8. Wipe the inside of each cup with a clean cloth. Inspect for signs of wear on needle bearings. Work carefully to avoid disturbing the bearings.

9. Wipe a dab of grease in each bearing cup and replace it. Press the cross back into the shaft, snap in retaining rings, and replace shaft on car.

Rear Axle

With a little luck you could wear out the engines in a half dozen automobiles and never have any trouble with the rear axle. The days are gone when wheel bearings and rear axle gears used to give out with regularity. In fact, it is sometimes a wonder why car makers put so much meat in their axles and rear ends. These units don't really need to be that tough, but we can be thankful they *are*.

A rear axle is basically a simple thing. Its essential purpose is to convert the driveshaft torque into thrust at the two rear wheels by using a form of bevel gear to turn the rotation through 90°. This is the "ring and pinion" gearset in the large center housing. The pinion is the small gear driven directly from the driveshaft, just behind the rear U-joint. This turns a large ring gear that turns the rear wheels. We also need a "differential" here so that one rear wheel can turn faster than the other when going around a corner. This is a small bevel planetary gearset inside the ring gear. The ring gear is bolted to the differential outer housing, and the axle shafts to the two rear wheels are splined into side gears, in turn connected to the ring through bevel pinions. This allows one wheel to overspeed the other and still feed torque to both of them.

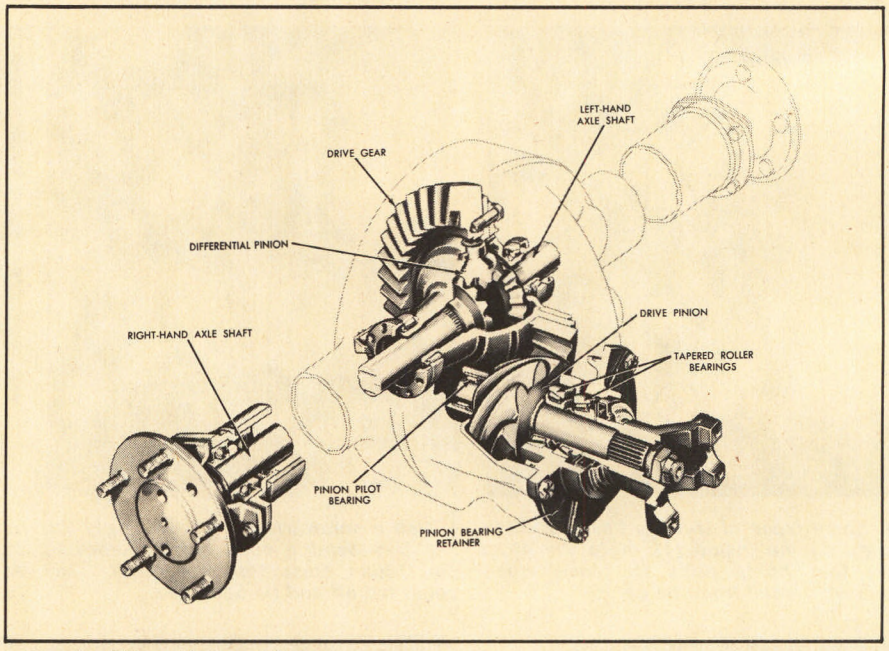
There's one serious disadvantage to a conventional differential. It exactly splits the total driveshaft torque between the two rear wheels. This means that if one wheel gets on ice or mud, there's no bite; the other wheel can't transmit any more torque—so the car sits there and spins one wheel while the other is doing nothing, even though it may be on dry ground. You've all seen this effect. This is also a problem on the drag strip, where driveshaft torque reaction tries to lift the right rear wheel and let it spin. Then the other wheel just doesn't do anything.

This is where your "limited-slip" (Posi-Traction, Equa-Lock, etc.) differentials come in. These have special clutches between the side gears and differential case to lock up the assembly when one wheel starts to spin. Some clutches are applied by springs, others have cams that increase clutch pressure as axle torque increases. Either way offers a big advantage on ice or on the drag strip. We suggest ordering a limited-slip differential (about $40 extra) on any high-performance car. Or you can get kits and install them on older cars.

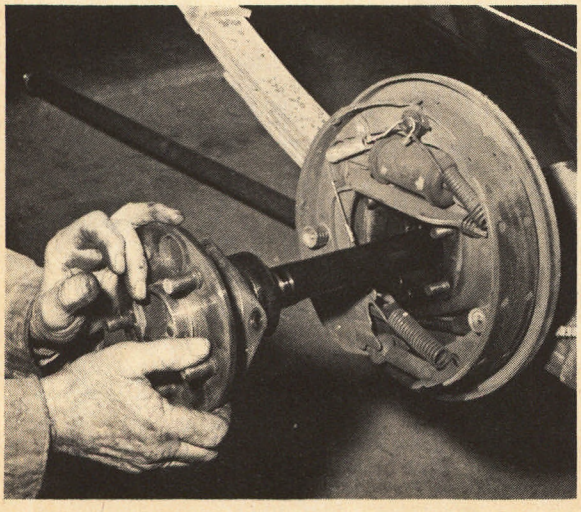
DIAGNOSING AXLE TROUBLES

Most rear axle trouble shows up in the form of some unusual noise from the axle, usually either gear noise in the ring and pinion (seldom the differential) or bearing noise in the outer ends of the axle housing.

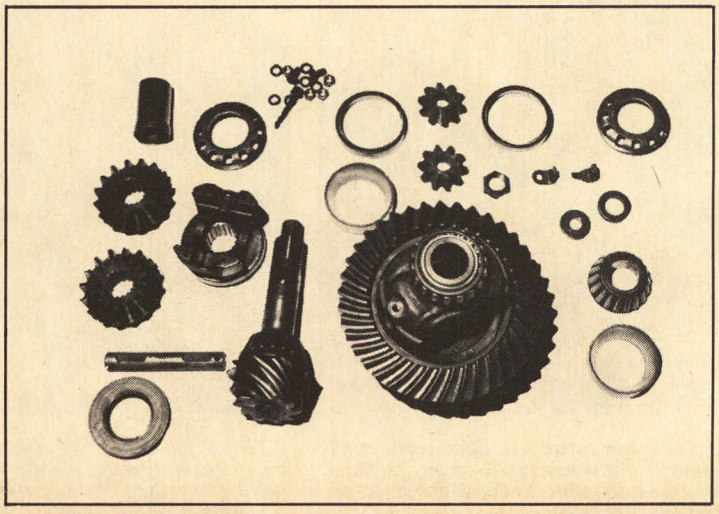
Gear noise is a rather high-pitched whine that tends to "cycle"—it gets louder and softer, sometimes higher and lower, in a definite rhythmic pattern. The



1. Standard Rear End and Axles



2. Removing Axle



3. Rear End Parts

noise is much more pronounced at certain car speeds than others. In fact it might also disappear at some speeds. You have to drive the car up and down the speed range on a smooth road to find it, checking under "pull" and "coast" conditions.

Bearing noise is entirely different. It has a lower-pitched whine or growl that remains quite steady, and tends to be louder when accelerating under load than when coasting. Most often the trouble will be in the wheel bearings at the outer ends of the axle (usually just one of them). It usually can be pinpointed by driving the car down the road and suddenly swerving to one side, then the other. This throws additional side load on the wheel bearings—and the growl should get louder. The best way to tell *which* bearing it is with this test (as a bearing can make noise with thrust in either direction or both): have someone ride in the trunk or rear seat to listen on both sides for the noise while you drive.

There's a chance the bad bearing could be one of the differential side bearings or the pinion bearing in the nose of the axle center section. In this case the whine would be higher pitched (because of the higher shaft speed) but would tend to remain steady. Also it would be louder under power, but would not change when you swerve the car on the road. Bearing trouble in the axle center section is much less likely than in the wheel bearings.

There are other possible axle troubles. A broken axle shaft is clear enough. The car won't move with a conventional differential, though it will move slightly under half-power with a limited-slip. A bad grease seal is clear enough—oil all over everything. Main grease seals are at the nose of the center section (just behind the rear U-joint), and at the wheel bearings at the outer ends. Usually it's the wheel bearing seals, as they are subjected to more stress forces under driving loads. Broken gear teeth in the differential are not common, but easy enough to detect. There will be a clunking feel each revolution. And a good fullpower run with teeth out will usually shuck out what's left—so the trouble won't be hidden for long!

MINOR AXLE SERVICE

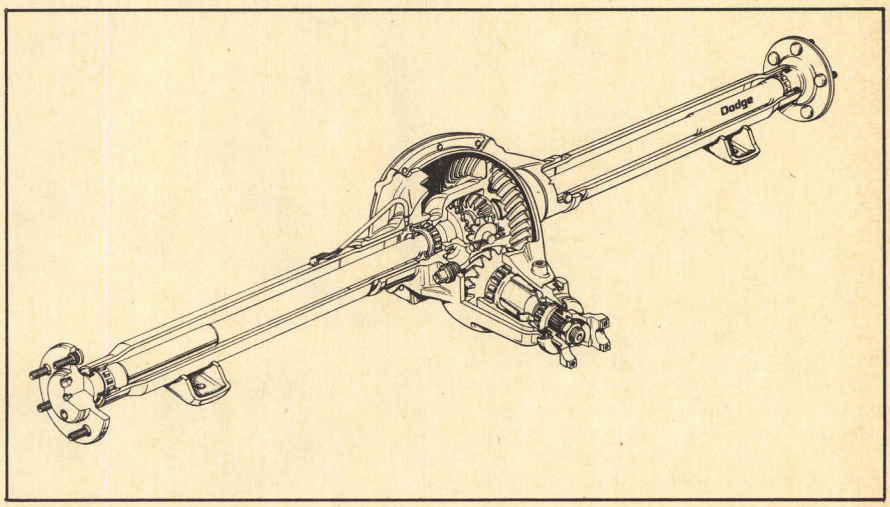
With a little experience, you can safely tackle some rear axle service, but not too much. It's too easy to mess things up. The simplest job is to pull the axle shafts and wheel bearings—either to replace a broken shaft, wheel bearing or outer grease seal. Even this will take some special tools, and you may have to have the bearing replaced at a garage. But you can pull the shafts, bearings, and seals on most late-model American cars with just a slide-hammer type axle puller and ordinary hand tools, which can be rented, borrowed or bought at a reasonable price.

AXLES WITH RETAINERS AT WHEELS

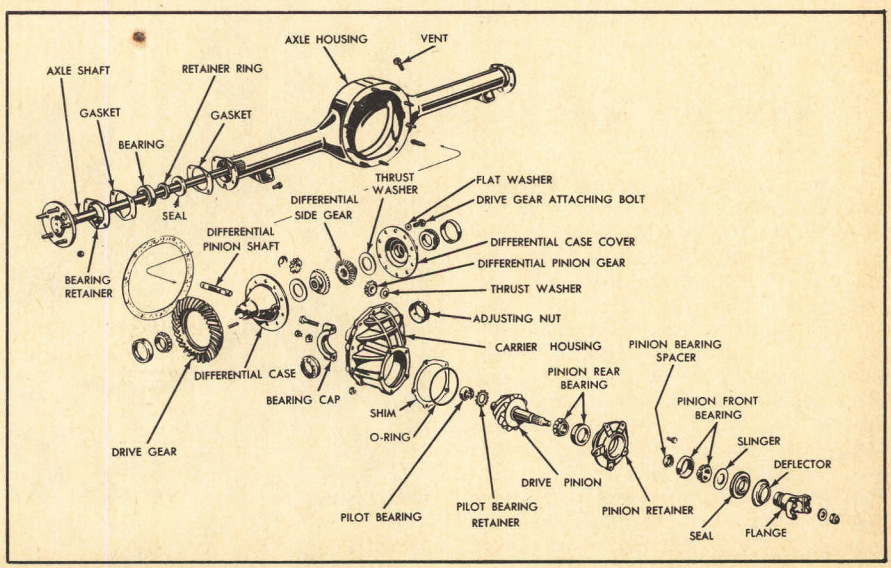
Jack up the rear end and remove the wheel lug nuts and the wheel. The brake drum is retained by these same nuts, and you can pull this off after the wheel. (It fits on there more snugly, so it will take some yanking—and a gasket may come with it.) When the drum is off, it will expose a broad flange on the end of the axle shaft (forged as part of the axle) that has studs spaced around it for the lug nuts. This is what you pull out of the axle housing; the shaft, bearings, and seals will come with it. But before it will come out you have to go behind the flange and remove the small bolts that hold on the axle bearing retainer plate and brake backing plate (which holds the shoes and cylinders). Remove these bolts and remove the retainer plate. But then put a couple of them back on to hold the brake in place, as this doesn't need to come off when changing axle shafts. Just tighten a couple of them up finger-tight and they will hold the brake.

Now you're ready for the axle-puller. This is a device that has a bracket on one end that attaches to the studs on your axle flange. There's a weight that slides back and forth on a rod attached to the bracket, and you can hammer this against the stop to pull the axle shaft and bearing out of the axle housing. Don't bang it too hard. Take it easy, and work the shaft out slowly so the jarring won't damage the ball bearings. You can buy one of these axle-pullers for your particular car at your car dealer, or universal types are available at any auto parts house. It's a good tool to have.

After the axle shaft and bearing are out, inspect them for wear, corrosion, and cracks. You can tell a bad bearing very easily. It will feel sloppy or rough—



4. Dodge Rear Axle



5. Rear Axle Assembly

1. The carrier side bearings are adjusted by means of a threaded ring in this design. Adjustment can only be done properly while the carrier is out of the axle housing.

2. The axle comes out with the bearing, after the bearing retainer has been unbolted from the backing plate.

3. Here are the component parts of a typical differential. While rugged and trouble-free, a differential is a piece of precision machinery that requires expert assembly.

4. Typical modern rear axle unit has inner retainers, straight roller bearings operating directly on the rear axle shafts themselves.

5. This type of differential and rear axle assembly disassembles from the front. It's probably best to let a specialist repair shop handle major rear end jobs.

that is, the outer race will be loose on the balls. Sometimes the balls are pitted and galled, and the central ball cage may be loose. Replace the bearing if you have any doubts at all, as they aren't expensive. However it does take a special tool and sometimes a press to remove the bearing and replace it, so you'll probably need to have this done at a shop. And this would also have to be done if you broke an axle shaft.

But if you're just replacing an outer grease seal, this can be done quite easily without removing the bearing from the shaft. There are different types and designs of seals, and sometimes there are two or three on both sides of the inner race of the bearing and a ring around the outside. Usually these rubber seals can be pried off with a screwdriver. This would damage them beyond repair, but you will always be replacing them anyway when you pull an axle shaft. Sometimes seals can be put back without special tools, or with a makeshift drift or collar. Just be careful not to damage the seal surface putting it back on the bearing. And always replace the seal with the open edge or flange facing the lubricant. If you put it on backwards, it won't work.

After everything is cleaned and lightly lubricated with chassis grease, you're ready to put the axle shaft back in. The first thing you have to do here is to run the shaft clear into the housing until you can feel it strike the differential side gear bearing or shaft. This will have splines that must fit the splines on the end of the axle shaft. You just have to feel around with the shaft in there until the end slides into the splines. You can't see anything. Just work it around until it slips in. Nothing to it.

From here you drive the bearing into the outer axle housing with the axle-puller, working in reverse as a drive hammer. (Or you could do it with a heavy hammer on the face of the axle flange.) When the bearing is seated in the axle housing, you just replace the bearing retainer plate (after removing the finger-tight bolts holding on the brake). Tighten these up good and snug. Then back go the brake drum and gasket, and finally the wheel and lug nuts.

AXLES WITH INNER RETAINERS

Chevrolet since 1965, and many other cars, do not have the retainer at the wheel behind the axle flange. After pulling the wheel and the brake drum, you will notice that there are no bolts in the area behind the axle flange that have anything to do with retaining either the axle or the bearing. This type of axle is held in place by a C-washer at the extreme inner end of the axle shaft. To remove the axle, you must remove the rear cover on the rear end housing, which of course lets all the oil run out. Then you have to remove a long screw that holds the differential pinion shaft in position so that the shaft can be pulled out of the differential carrier. Once the shaft is out of the way, the axle shaft can be pushed inward enough to free the C-washer, which will then fall out into your hand. Once the C-washer is out, you can slide the axle out of the housing. The bearing and seal are pressed into the end of the housing and must be removed with a slide hammer puller that will reach in and pull from behind the bearing.

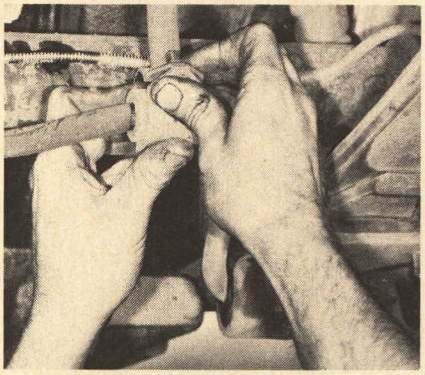
THE CENTER SECTION

There are two general types of rear axle center-section designs on modern American cars. The most common is where the main axle and differential housing is like a large banjo in the center, with tubes tapering off on each side for the axle shafts and to hold the wheels. The banjo is closed at the back. Then the gears and differential are carried in a cast iron "carrier" that bolts to the front of the banjo. You can get to the gears by merely unbolting the carrier and pulling it out.

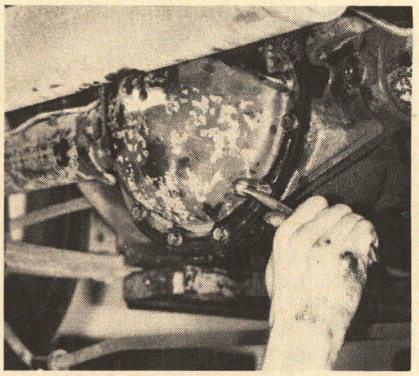
In the other layout, the carrier housing is much larger and contains the entire differential. The side axle tube housings are pressed into this carrier casting, and it's closed at the back by a stamped cover that bolts on. This design is used for the late Chevrolet axle and the small Chrysler models, etc. It has the advantage of keeping all parts in a bit more rigid alignment, but it's harder to work on the gears and seals. In both cases, of course, when removing the carrier, you must disconnect the rear U-joint, drop the driveshaft, and pull out the axle shafts from the outer ends of the axle housing (as outlined earlier).

Obviously any center-section service work will be quite a bit easier on axles with a removable carrier. Here you just unbolt the carrier from the banjo housing and pull it out (after you remove the axles). All gear adjustments can be made right on the carrier assembly. And you can put the assembly up on a bench to work on it. With the "integral"-type axle (late Chevrolets, etc.) you either have to pull the entire axle out of the car to work on it, or put the car up on a hoist and work from underneath.

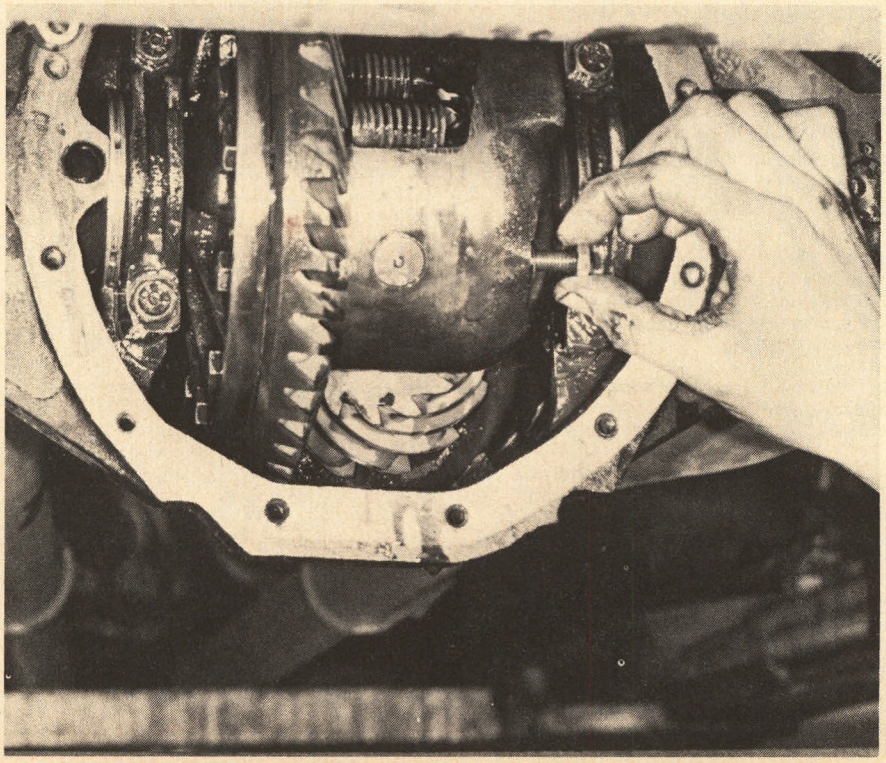
Rear end gear adjustments are critical for low axle noise, especially with these "stiff" 4.11 and 4.56 ratios. For instance,



1. Unbolting Sway Bar Shackles



2. Removing Differential Cover



3. Removing Pinion Shaft Lock Screw

gear "lash" (the distance a tooth on the ring or pinion can be moved back and forth before contacting the next tooth) must be held generally between .004 and .008-in. That's pretty tight. Lash is adjusted by shim spacers on the pinion stem and at the differential side bearings. (These adjustments move the pinion gear back and forth and the ring gear from side to side, respectively.) Needless to say, making these adjustments is complicated work. Not only do you need special tools to get at the adjusting shims, but you need a pretty sophisticated dial indicator rig just to *check* lash. So this is best left to pros.

But you can save plenty of money by removing your own replaceable carrier assembly (on 90% of cars) and taking it into the shop for work. Then you won't pay labor for removing this from the axle. You can fairly well tell whether your gears need adjustment by gear whine on the road—which you can interpret from instructions earlier in this chapter. Also a quick inspection of the ring and pinion gear teeth can tell a lot about gear lash. If adjustment is right, the wear pattern (where it is shiny and smooth) should be right in the middle of the tooth face. This is both across the tooth and up and down on the tooth. Right in the middle. If there is a wear spot at one end of one tooth and at the other end of the mating tooth, or if the wear spots are high up on the tooth or low down, or if they are egg-shaped and slightly off center or slightly tilted...you can be sure your gear adjustment needs attention.

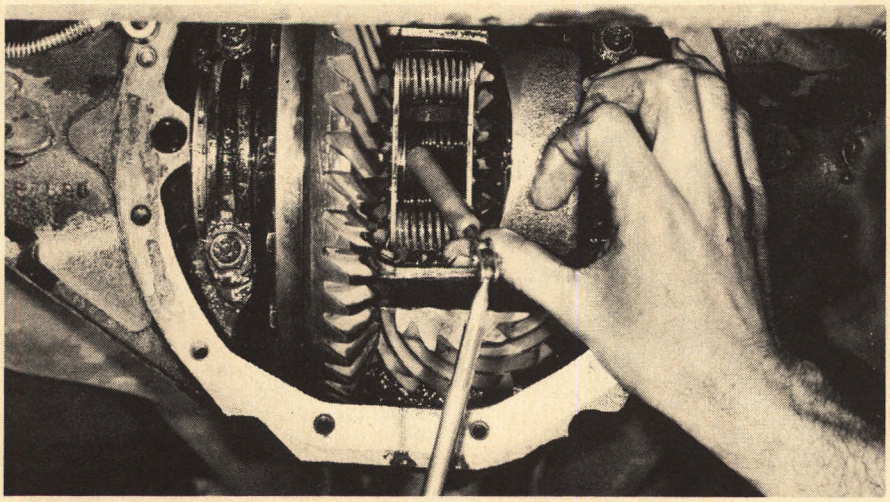
One more word about center-section work: If you break an axle shaft on your car, you will need to pull both the axle shaft and the carrier section. This is because the broken end of the shaft can't come out with the main part of the shaft—as they usually break near the splines at the center section. So you would need to pull the carrier to fish the broken end out. However, if an axle breaks beyond the spline, you might be able to bend up a tool out of a coat hanger to "fish" out the broken end without removal of the center section.

DETERMINING AXLE RATIO

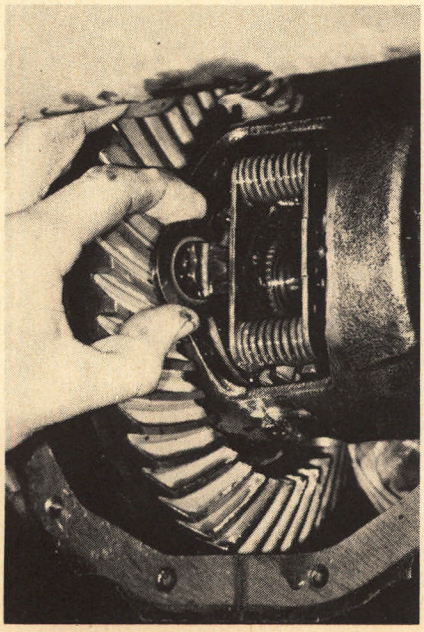
Rear axle gear ratio has a huge effect on the acceleration performance of a car, as most of you know. This ratio determines how fast the engine turns in relation to rear wheel rotation, or the car speed. With a 3.55:1 ratio, for instance, the driveshaft would turn 3.55 times for each 1 full turn of the rear wheels. (This would be in high gear; but if the transmission is in low or second, the engine would be turning more than 3.55 turns per 1 turn of the wheels.) In general, the faster the engine turns in relation to car speed, the snappier the acceleration. There have been cases where just changing the axle ratio from 3.55 to 4.11 has knocked a full second off the elapsed time (e.t.) at the drag strip! This is quite a hop-up weapon.

So it's important for you to know the axle gear ratio that's in your car. In most cases you will have a pretty good idea by the standard ratio that is supposed to be in that model, from the factory catalog. If you bought the car new, there may be a listing of the ratio on the invoice or price sticker. Also on assembly-line cars there is always a mark or number stamped on the differential housing that indicates the ratio that was put in that axle at the factory (and whether it's a standard differential or limited-slip). Unfortunately each company uses its own code of numbers or letters to indicate these ratios. There would be no way you could interpret them without consulting the shop manual for your model. Space won't permit any detailed list here, but any car dealer will help you.

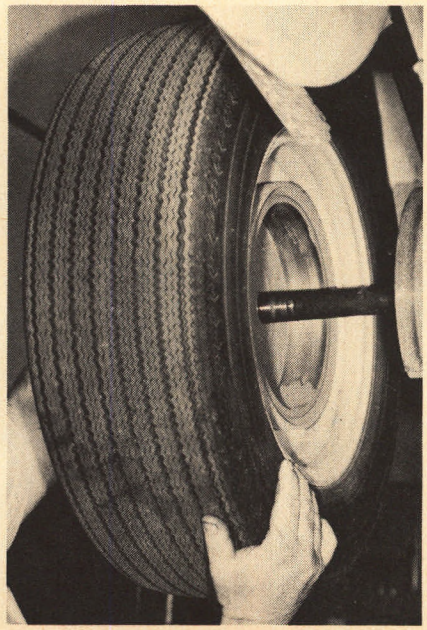
Gear ratios do get switched around from time to time—and you may still not be sure of the ratio that's in your car. This will require actually measuring it. It's simple! Make a chalk mark horizontally at some point on the driveshaft and a vertical mark on the outside edge of the tire. Block the front wheels, jack up the rear end and put the transmission in neutral. Now turn the driveshaft around slowly (accurately counting the revolutions) and have someone tell you when the rear tire has made exactly one full revolution.



4. Using Magnetized Rod



5. Removing the C-Lock



6. Pulling Shaft From Housing

1. If your car uses a rear anti-sway bar like this Pontiac Trans-Am, you'll have to unbolt the shackles and swing the bar out of the way.

2. Place a container beneath the differential before removing the cover. This comes under the heading of good housekeeping.

3. After the differential has been drained, wipe exposed parts dry and remove the lock screw holding the pinion shaft in place.

4. You'll have to push each wheel in toward the differential in order to remove the C-lock from button end of axle shaft. A magnetized rod makes removal easy.

5. The C-lock is the key to differential reassembly, so for heaven's sake don't lose it. Pull it out and put it where you can find it again later.

6. Remove the axle shaft from the housing by pulling outward. Be careful not to damage the oil seal in the differential when pulling axle out.

Rear Axle

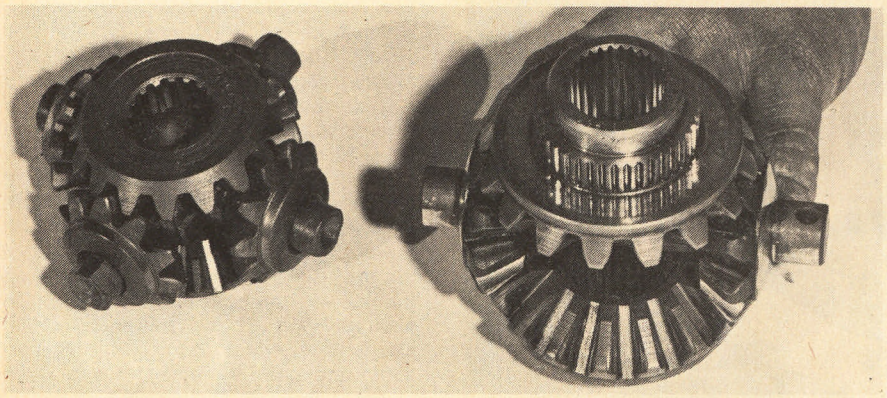
You can't get an exact measure of the ratio this way, because it's hard to pinpoint accurately the degrees of rotation of the driveshaft when the wheel has made its full turn. But you can tell the difference between the various ratios that are available for your model in the catalog. Let's say the catalog lists optional ratios of 3.08, 3.36, 3.55 and 3.70 for your car model. You could tell the difference between these. The 3.08 ratio would be just a shade more than 3 turns of the driveshaft. The 3.36 gears would be about 3⅓; the 3.55's, 3½; and the 3.70 gears would see the shaft turn roughly 3¾ times for one turn of the wheels.

HOPPING-UP WITH GEARS

As we have said, putting stiffer axle gears in your car—gears with a numerically higher ratio—is one of the simplest and cheapest ways to hop-up the acceleration performance. And, fortunately, you can now get a wide range of gear ratios for almost any late-model car, either through a factory parts warehouse or from one of the specialty suppliers like Getz Products or Precision Gear. These available ratios run from as low as 2.56 to 6.17 or more. Something here to fit every need. And the prices are not impossible. Usually from a low of around $40 for a set of factory gears to $75 to $100 for special-cut performance and racing gears. Get a catalog and do some shopping.

Space won't permit any deep discussion of optimum gear ratios for various performance requirements. But it's not hard to come up with some suggestions that won't be far off the mark, since the science of gear selection has become very refined in the hot rod field in the last five years—especially as more ratios become available for various car models. For instance, we know that a ratio somewhere around 3.5 is best for top speed on most cars. This ratio is also a pretty good compromise for the street and highway. (You'll note that many high-performance factory cars have standard ratios in this range.) If you do most of your driving on the open highway, we would suggest a ratio closer to 3.0:1. On the other hand, if you do most of your driving at moderate speeds around town, and want a lot of pep on the street, try gears around 3.9. Actually 4.11 would be even stronger. For the drag strip, most full-bodied stock and modified stock cars (even Super/Stocks) like ratios of 4.56 or 4.88. These allow the engine to just peak going across the finish line. Your 5.12 and 5.37 gears are for small-engine Gas Coupes that want to wind up 7000 to 8000 rpm at trap speeds of 100 to 120 mph. Ratios from here on up are pretty much for track racing on short ¼- and ½-mile ovals, where your car speed might be only 60 to 80 mph and you want an engine speed of 5000 to 6500 rpm. It's either run these wild ratios or run in 2nd gear all the time!

In conclusion, a word about installing these special gears. Here again it's a job for a professional. In fact, high ratios from 4.11 on up seem to take extra precaution on gear lash to get away from whine on the road. Gear noise is definitely more of a problem with high-ratio performance gears. So we would suggest that you just pull out your axle carrier section, take it and the new set of gears down to an experienced mechanic, and let him make the change and adjustment. The job requires pulling the pinion stem, the differential case and side bearings—and it requires a lot of special tools. Don't try to do it unless you have the help and advice of somebody with experience—*plus* the proper tools.

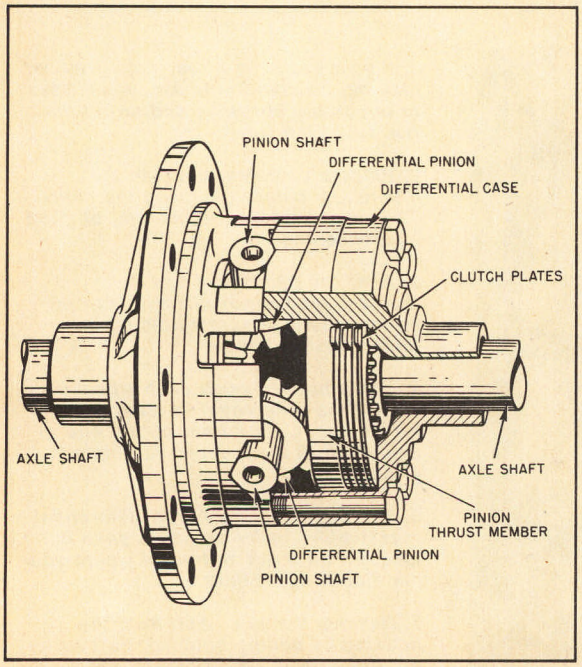


1. Differential Side and Pinion Gears

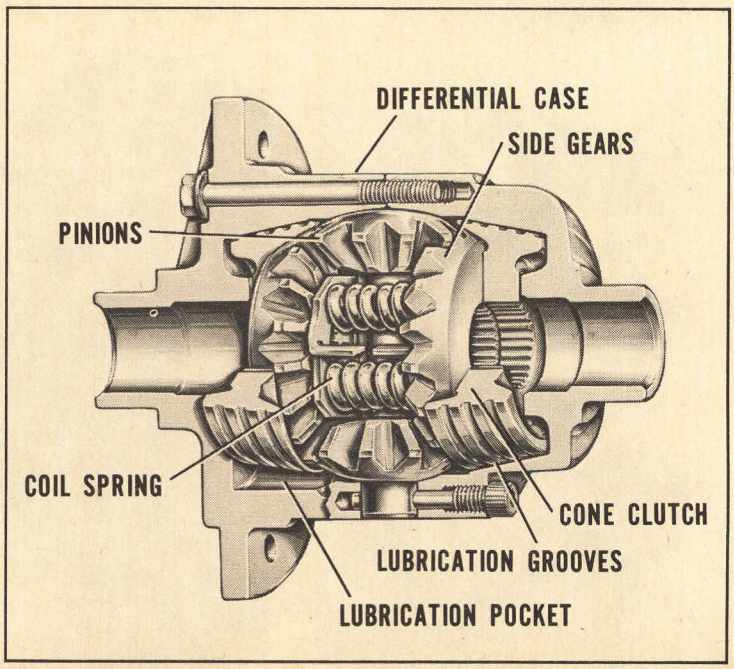
1. Comparison of two limited-slip differential spiders. Design at left requires four pinion gears between the side gears for high torque capability in small size.

2. Assembly of limited-slip differential. Amount of preload is critical; too little and an unloaded wheel will spin uselessly, too much and the differential will act like a locked rear end when negotiating a corner.

3. This type of limited-slip differential uses cone clutches in place of plate clutch packs. Advantages are fewer parts, simpler design, better lubrication, and longer life.

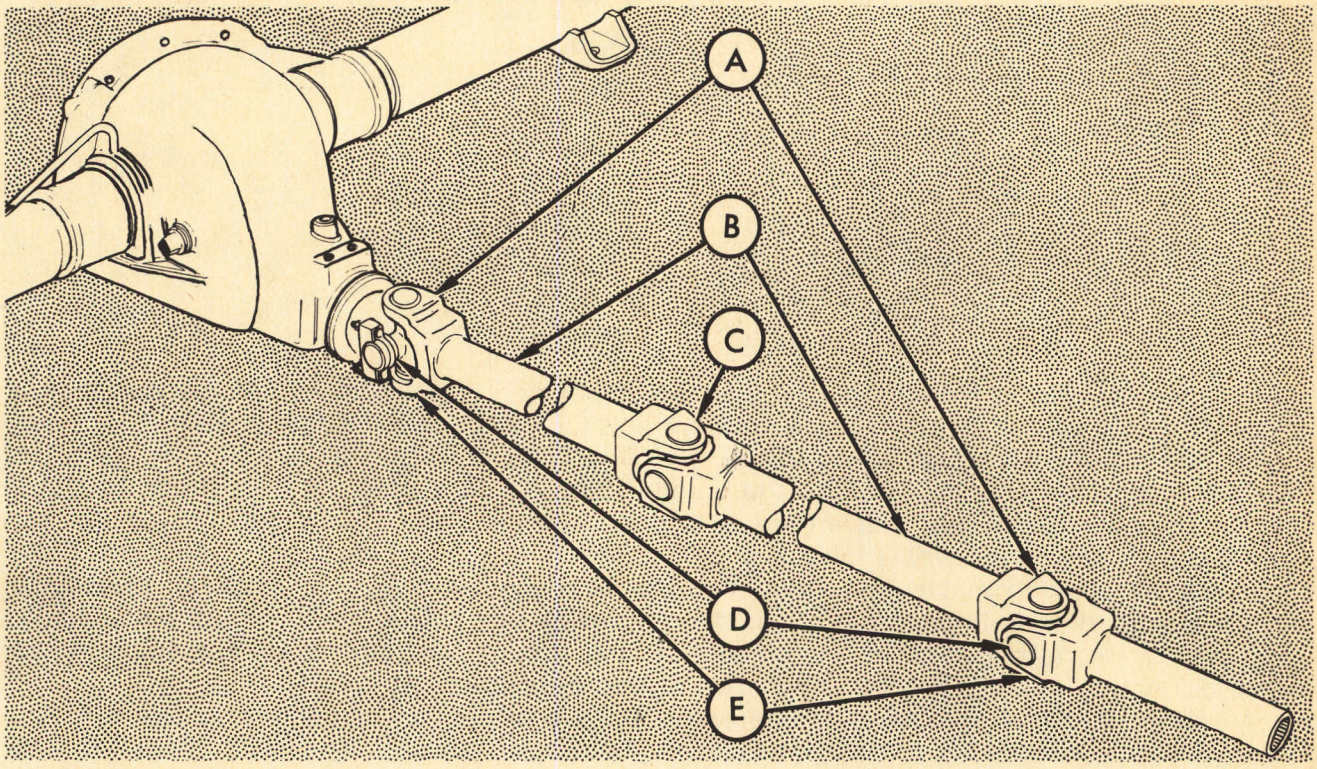


2. Chrysler Limited-Slip Differential

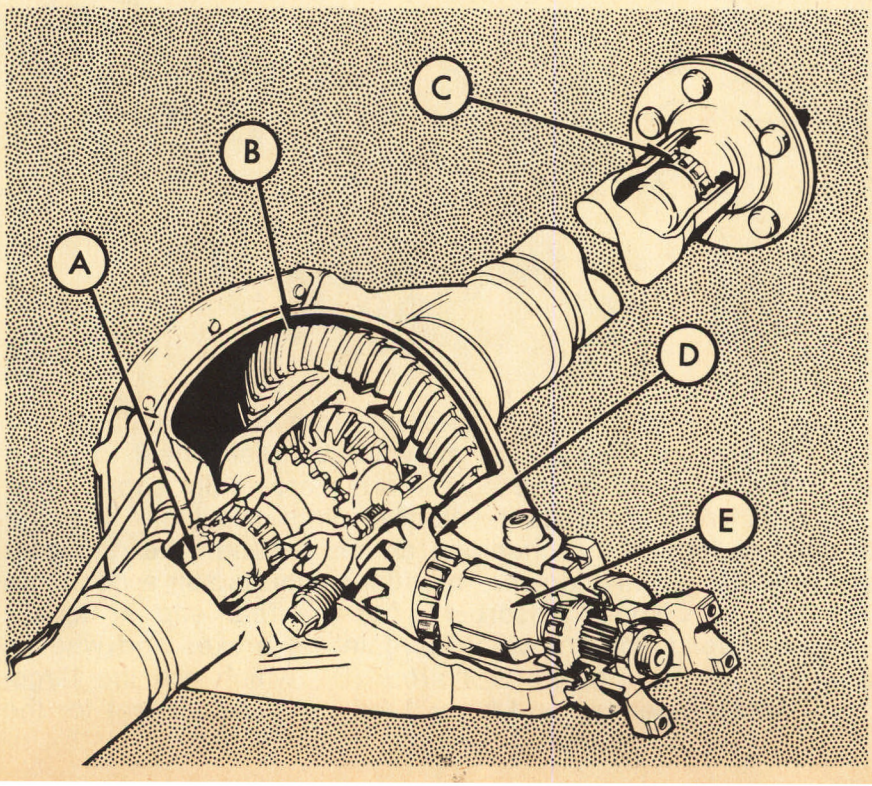


3. Cone-Clutch Limited-Slip

TROUBLESHOOTING DRIVELINE/REAR AXLE

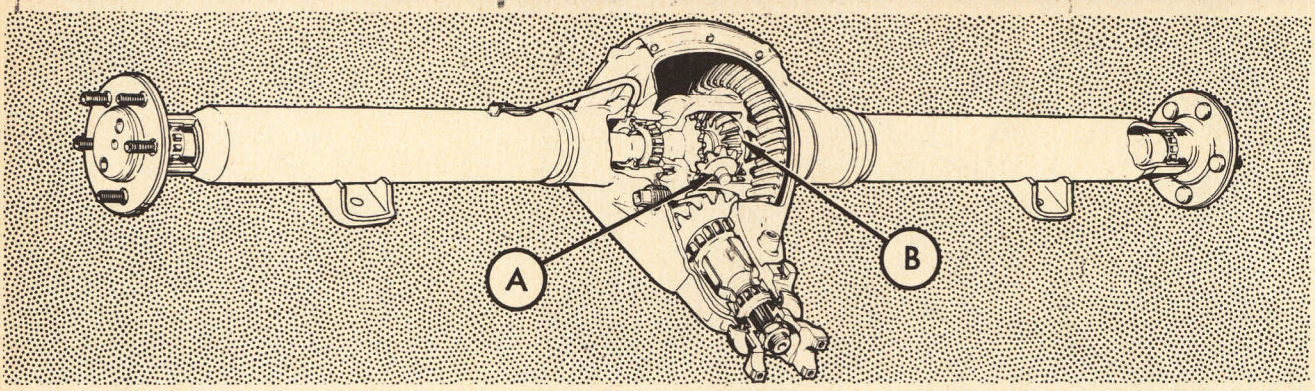


Engine torque from the transmission is routed to the rear axle by the driveshaft (B). This is a hollow metal tube connected at each end by universal joints (A), called U-joints. The U-joints are designed to allow the rear axle to move on its springs without binding or stopping the driveshaft rotation. The U-joint consists of a cross-shaped casting (D) suspended between two C-shaped holders (E). The holders (E) are set at right angles to each other and the ends of the casting are held in bearings. This allows the joint to swivel 360° without interference. On some cars, due to their construction (four-wheel drive and some longer vehicles), there may be an additional U-joint (C) in the middle of the driveshaft, making in reality two driveshafts.



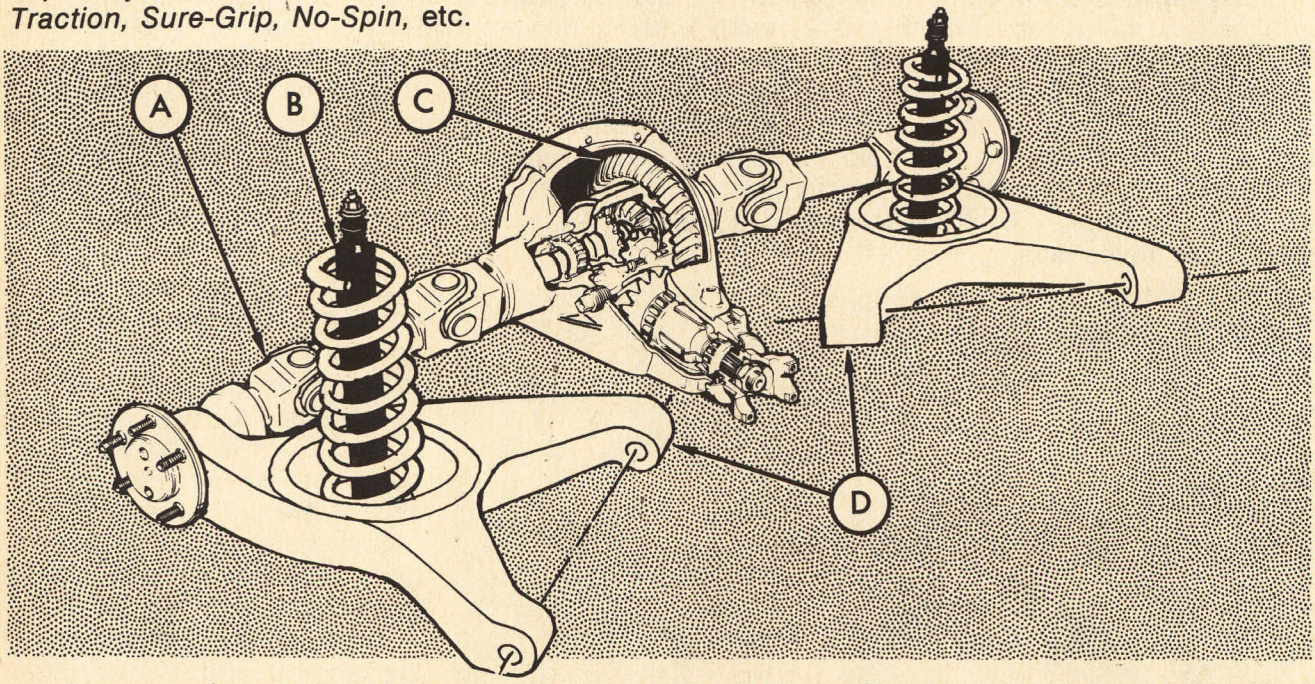
The rear of the driveshaft connects to a pinion shaft (E) on the rear end. Inside the rear end housing is a set of gears which convert the rotary motion of the driveshaft to drive the rear wheels. On the end of the pinion shaft is the pinion gear (D). The pinion gear meshes with a larger gear called the ring gear (B). Rotation of the driveshaft by the engine and transmission causes the pinion gear to drive the ring gear, rotating the axles (A). The outer ends of the axles are supported by axle bearings (C), which have grease seals to contain the lubricant for the bearings inside the axle housing. Bolted to the ends of the axles are flanges to support the drums and wheels.

TROUBLESHOOTING DRIVELINE/REAR AXLE



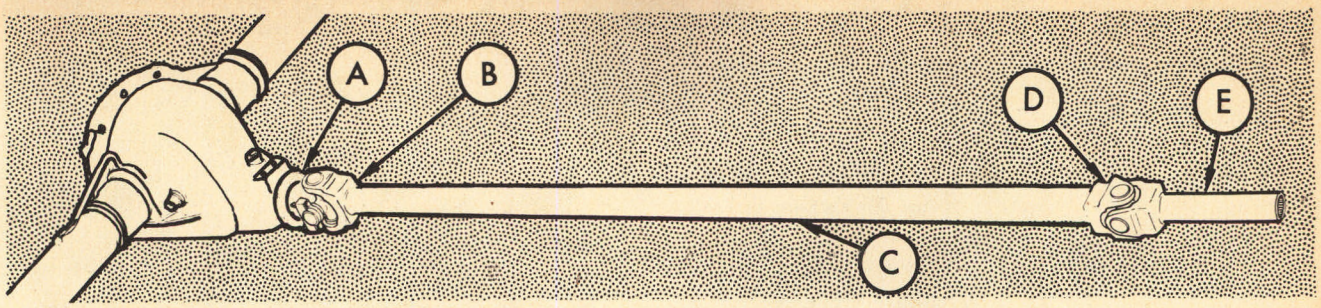
The gear set (B) in the middle of the rear end housing is much more complicated than a simple ring and pinion gear. There are small sets of gears called spider gears (A). These provide the differential action which allows the car to change direction without damaging the tires. When the car is going straight, the spider gears do not rotate on their shaft. They are only turning two side gears with an equal torque from the main pinion gear. When the car turns a corner, the inside wheel follows a shorter line than the outside wheel. This causes the inside axle to want to make *fewer* revolutions than the outside axle. The spider gears take care of this by rotating in such a manner that the inside axle can slow down without damage. Once the car has turned through the corner and has straightened out again, the spider gears cease to function and again both axles drive at the same speed.

A variation of this, the locking differential, uses a system of clutch plates and discs to perform the same process but still applies engine torque to both wheels for better driving capability in mud or sand. This feature is known under various trade names such as *Posi-Traction, Sure-Grip, No-Spin,* etc.



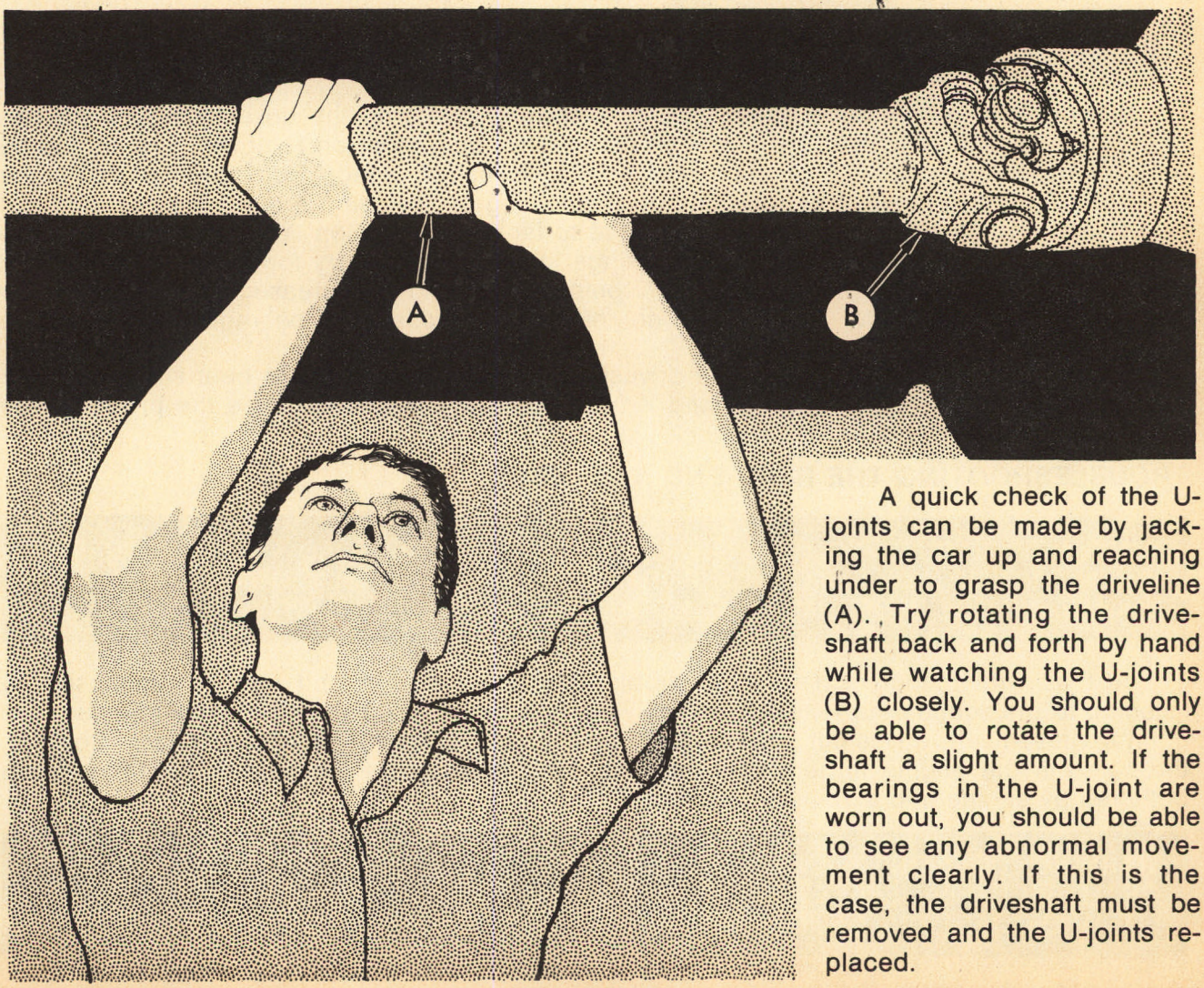
Many modern automobiles have a rear axle design different from the one described above and known as independent suspension. This design allows each rear wheel to move freely, independent of the other. The axles used in these rear ends are really short driveshafts which may have either U-joints (A) or constant-velocity joints (basically like the U-joint described earlier) at both ends to handle the changing angles between the ring gear (C) and the wheel as the suspension works up and down. The suspension is still a combination of springs (B), either coil or leaf, and shock absorbers, but the rear end is usually fastened directly to the frame and the outer members which contain the brakes and wheels. The rear axle, with brakes and wheels, is held by control arms (D), which are the large, stamped steel parts that support the entire assembly and keep it from moving, except for the up and down motion required.

TROUBLESHOOTING THE DRIVESHAFT



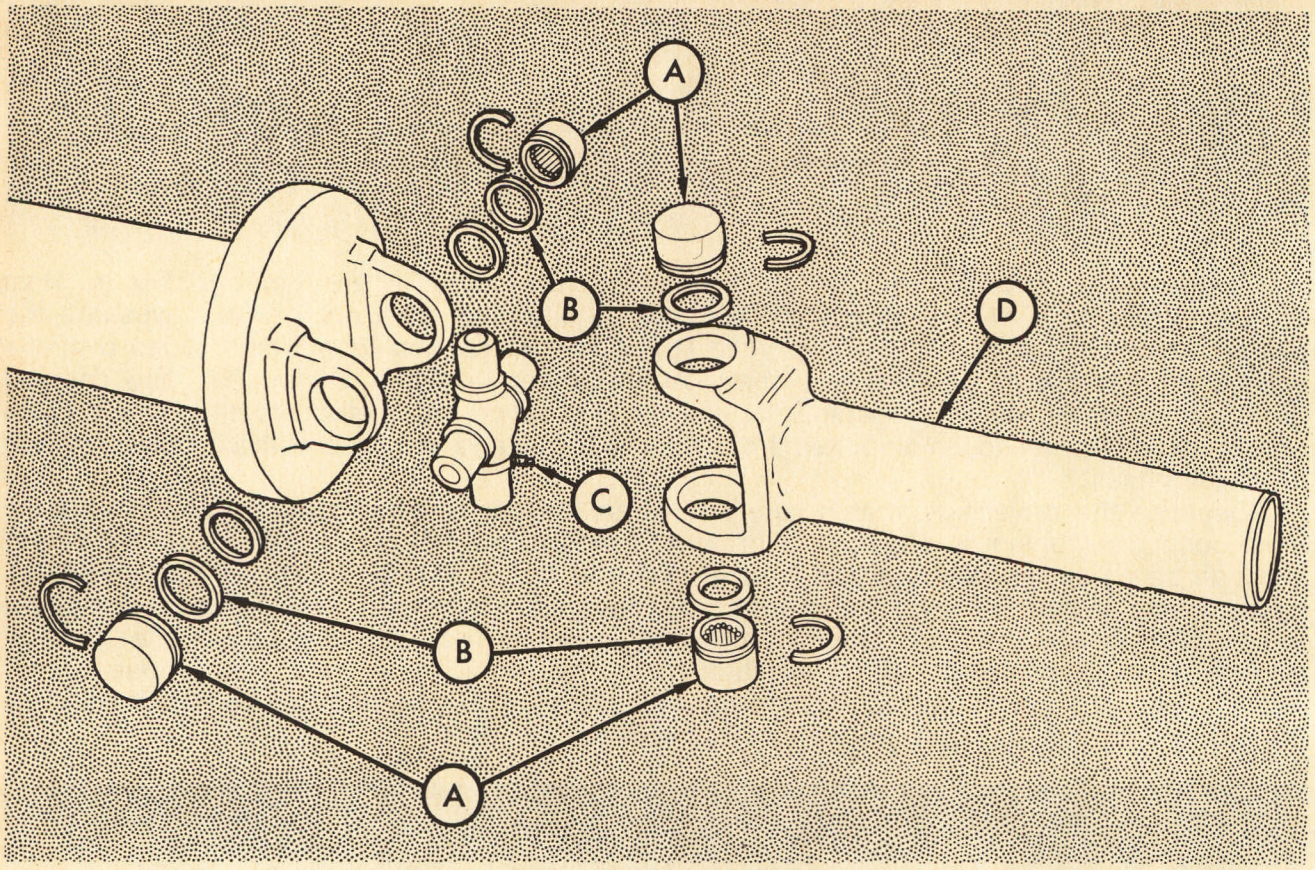
Because the driveshaft (C) is such a simple device, it is easy to check out. Most driveshaft problems will be associated with the U-joints. At the front of the driveshaft, the forward U-joint (D) attaches to a slip yoke (E), a hollow, splined tube which slides over the splines on the transmission output shaft. At the other end, the U-joint (B) may connect directly to a shaft or to a companion flange (A). This flange is a method of attachment which allows the driveshaft to be unbolted from the rear end and removed without disassembling the U-joint itself.

Because the driveshaft rotates very fast when the car is moving at highway speeds, its most common problem is vibration. Vibration is most often noticed at certain speed ranges and can be confused with rear end, suspension and tire problems. Tire noise can be detected by driving the car on a variety of surfaces. Changes in the vibration or noise level indicate the problem is with the tires rather than the driveshaft or rear end. Engine noise or exhaust noise can be distinguished from driveshaft noises by running the engine at various speeds with the transmission in neutral and the car motionless. If the vibration or noise occurs while the car is standing still, it cannot be coming from the driveline.



A quick check of the U-joints can be made by jacking the car up and reaching under to grasp the driveline (A). Try rotating the driveshaft back and forth by hand while watching the U-joints (B) closely. You should only be able to rotate the driveshaft a slight amount. If the bearings in the U-joint are worn out, you should be able to see any abnormal movement clearly. If this is the case, the driveshaft must be removed and the U-joints replaced.

TROUBLESHOOTING DRIVELINE/REAR AXLE



A sticking U-joint is more difficult to verify without removing the driveshaft from the car. With the driveshaft removed (see the shop manual for instruction on removal), you should be able to move the yokes (D) at each end of the driveshaft without too much effort. If the U-joints are hard to move, look for signs of overheating or corrosion around the bearing caps (A). This is an indication of bearing failure due to lack of lubrication. Your U-joints may have fittings (C) called zerks to lubricate the bearings. If so, you might try forcing fresh lubrication into the bearings to see if rust and dirt come out around the grease seals (B) on each bearing. In any event, the U-joints are not expensive and should be replaced if they are suspected.

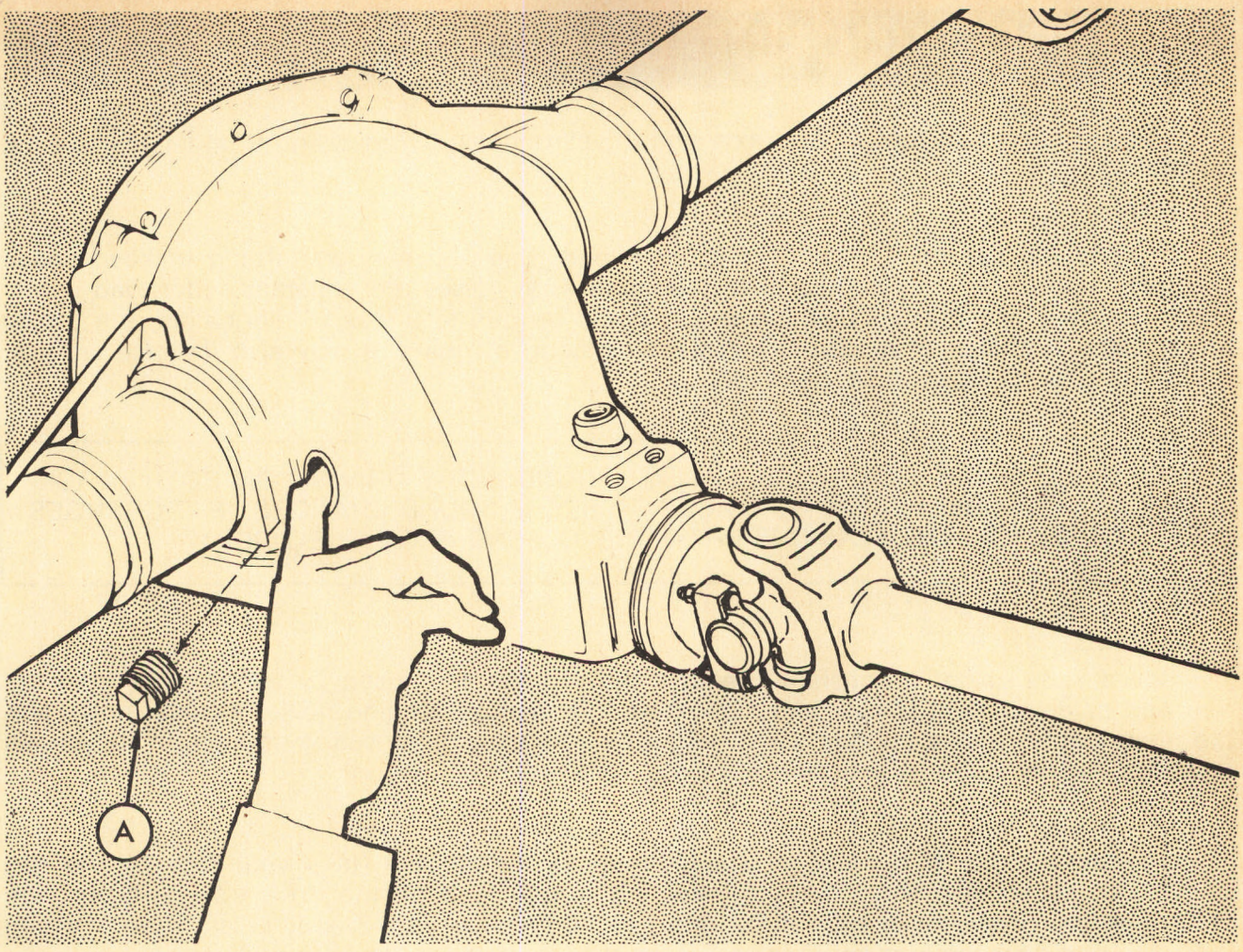
Another common problem with the driveshaft is an out-of-balance or bent shaft. Both are hard to check without special tools, and if the U-joints do not seem to be the problem, see your local mechanic and have him check the shaft properly.

TROUBLESHOOTING THE REAR END ASSEMBLY

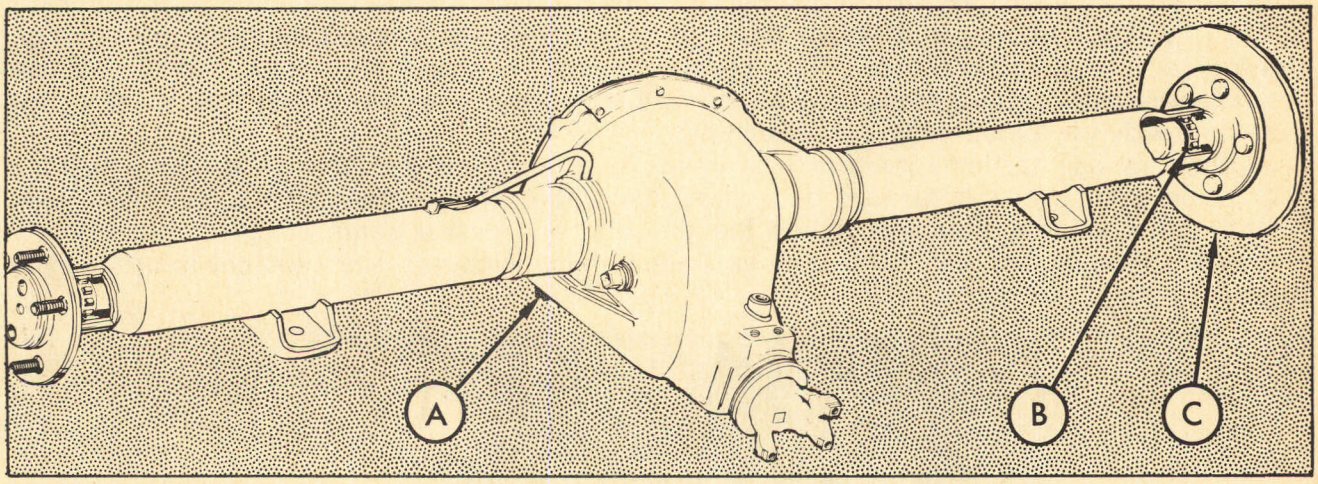
WARNING: BE SURE YOU HAVE OPEN STRETCHES OF ROAD WITH NO TRAFFIC WHEN ATTEMPTING TO CHECK FOR REAR END ASSEMBLY NOISE. THIS TEST SHOULD NOT BE PERFORMED IN ANY TRAFFIC SITUATION.

Just as with the driveshaft, most problems inside the rear end can be diagnosed by listening to the sounds the rear end makes while the car is being driven. Rear end noises are often confused with driveshaft, tire, clutch, transmission and exhaust system noises. Coasting the car with the engine turned off is one way of checking out the rear end without being bothered by engine and exhaust sounds.

WARNING: COASTING CAN BE DANGEROUS. DO NOT COAST DOWN STEEP HILLS OR AT EXCESSIVE SPEEDS. SELECT AN OPEN AREA SUCH AS AN EMPTY PARKING LOT AND COAST ONLY FOR SHORT DISTANCES AT LOW SPEEDS.



Lubrication level is checked by removing the filler plug (A). The lubricant should be within finger distance of the opening and should be clean and fresh. Lubrication for rear end gears is specially designed for the type of installation by the manufacturer. Always use the recommended lubricant listed in the owner's manual or shop manual.



If you suspect a problem in the rear end, the first step is to check the level of lubricant in the housing. Look for leaks around the drain plug (A) or at the axle seals (B) on the ends of the axle housings. Lubrication loss at the axle seals can usually be seen on the inside of the wheels or tires.

NOTE: LEAKING BRAKE FLUID CAN BE CONFUSED WITH REAR END LUBRICATION. IF THERE IS CONSIDERABLE FLUID ON THE WHEEL BACKING PLATES (C) OR INNER SURFACES OF THE TIRES, CHECK THE BRAKE SYSTEM.

TROUBLESHOOTING DRIVELINE/REAR AXLE

The car can be tested for rear axle and driveline noise by operating it under four driving conditions:

DRIVE

Operate the car on a straight and level road. Use just enough throttle to keep speed gradually increasing. This should help determine what noises are constant under load conditions. A steady whining or humming sound could be due to a loss of lubrication, the use of an improper lubricant or incorrect mesh (adjustment) of gears. It may also indicate worn or dry (require lubrication) wheel bearings.

NOTE: TIRE NOISE CAN CAUSE SIMILAR SOUNDS. TRY DRIVING ON BOTH BLACKTOP AND CONCRETE ROAD SURFACES TO SEE IF SOUND CHANGES. IF IT CHANGES OR DISAPPEARS, THE SOUND IS PROBABLY COMING FROM THE TIRES.

CRUISE

Operate the car at a constant speed. If the problem is caused by things other than the rear end or driveline, it should show up using this method. Engine noise, exhaust noise and tire noise can all make sounds which might be mistaken for driveline sounds. In the cruise test, they will be easier to hear and eliminate.

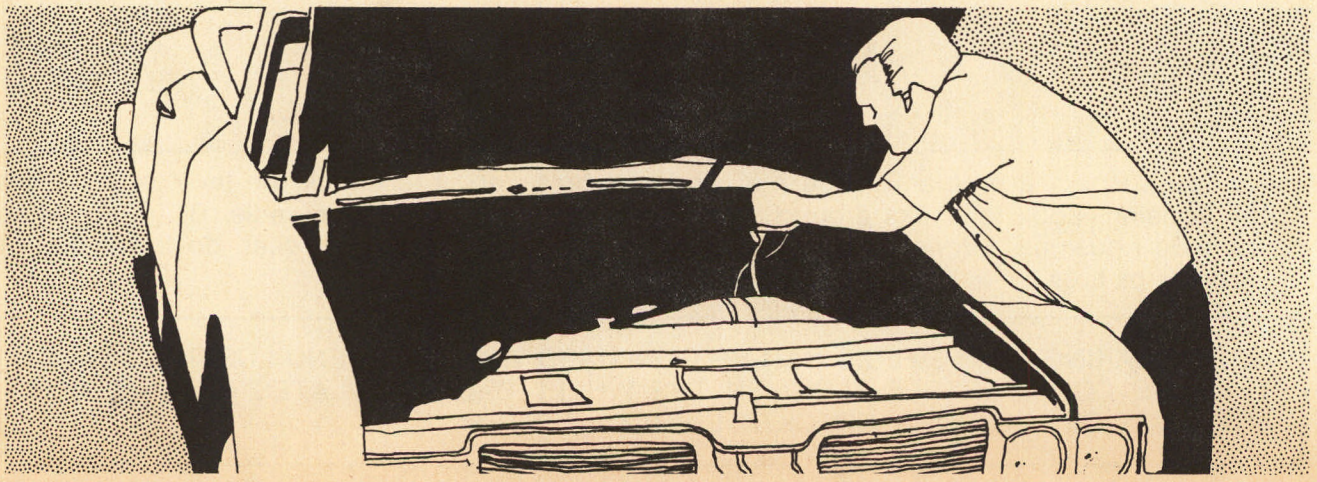
COASTING

Operate the car at a constant speed. Release the throttle (take your foot off the gas pedal) and let speed decrease. This takes the torque load off the drive train and puts the vehicle weight on the back side of the ring gear in the rear end. Steady noise when coasting indicates bad gear teeth or improper adjustment of bearings in the rear end assembly.

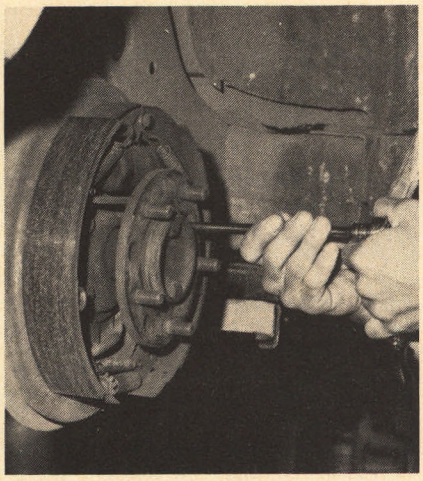
ALTERNATING SPEEDS

This is a combination of the methods already described. Starting with the car at a steady speed, accelerate slightly. (Low road speeds are best here; speed should not exceed 10 mph.) Then take your foot off the gas pedal suddenly. This will cause sudden torque transfer in the driveline and rear end. Worn bearings inside the rear end assembly or in the wheel bearings or excessive clearance (wear) between gears will produce a sharp "clunking" noise. Worn U-joints can also produce this sound, but if you are troubleshooting step by step, you should already have inspected the driveshaft.

Other noises that indicate problems in the rear end and driveline are a sharp metallic click when shifting from a forward gear to reverse and clicking when turning a corner. These sounds indicate loose nuts or chipped teeth in ring and pinion gears or spider gears in the rear end. If you don't hear noise until you are turning a corner, the problem is probably in the spider gears of the rear end.



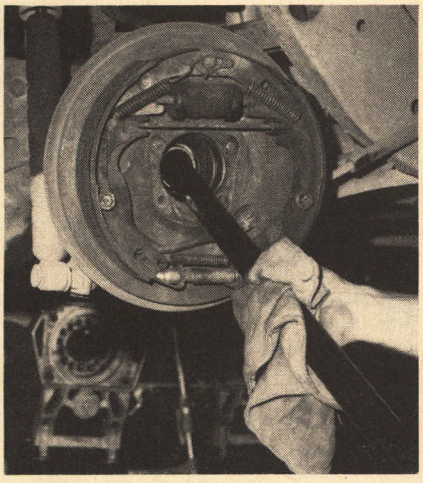
HOW-TO: Replacing Rear Axle Bearings



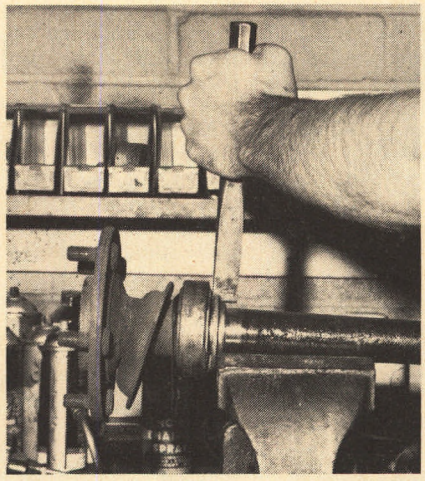
1. First step in changing an outer bearing is removing wheel and drum, then undoing the four axle retaining bolts through hole in axle flange.

2. If you're doing the job at home, you can usually get the axle out by putting the wheel back on and hitting the tire outward with a big hammer.

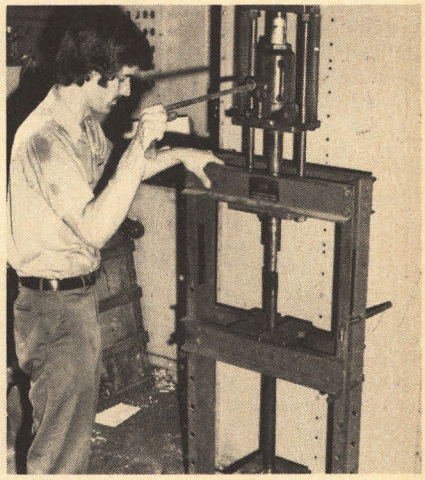
3. Best way to remove axles is with puller like this. Ron Griffin of Griffin Automotive, N. Hollywood, Calif. shows how with this slide-hammer.



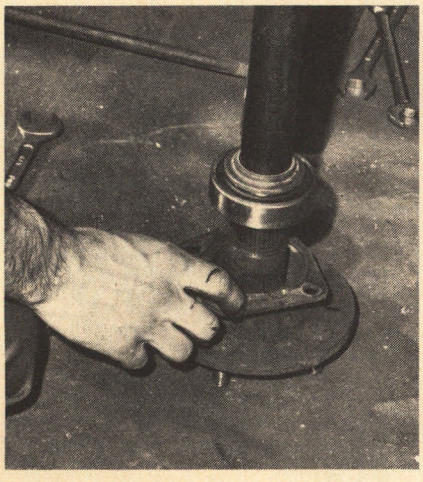
4. The inside seal also needs to be replaced, and you can use the end of the axle itself to pry it out once the axle comes loose of differential.



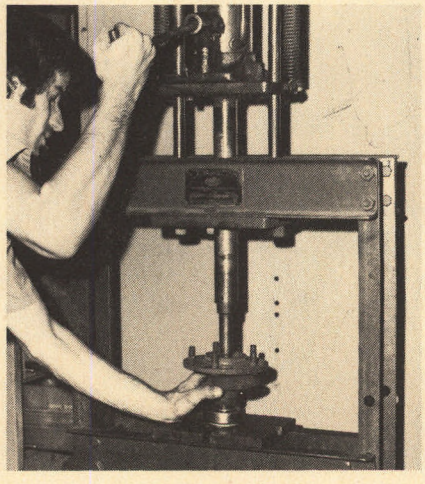
5. On this Olds axle, the bearing is held on by a retainer ring, which must be chiseled off—but be careful not to nick the axle bearing surface.



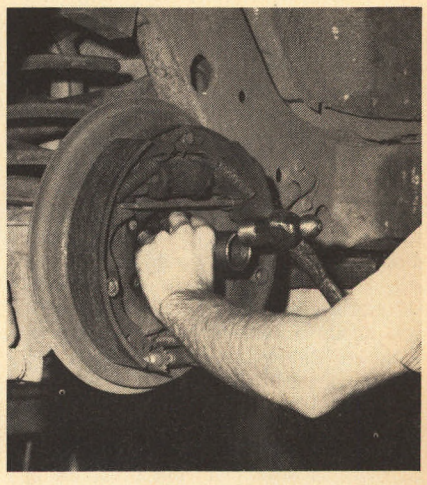
6. Some people cut old bearings with a torch, but the right way is with a press. Any auto parts machine shop can press off the bearing for you.



7. Before slipping new bearing and inside retainer on axle, be sure the outer retainer (with new gasket) is on axle and facing right direction.



8. Once again, a hydraulic press is the only right way to install the new bearing. It should be pressed on until it seats on axle shoulder.



9. Before installing the axle with its new bearing, you must tap a new seal into the housing with a socket, or other round driver, and hammer.

Brakes-Drum & Disc

Brakes don't ordinarily go bad all at once. It just seems that way. You might drive for many thousands of miles and never have a bit of trouble with your brakes. Then one day you have to make a panic stop and you discover that you would probably get to a halt quicker if you dragged your foot through a hole in the floorboards. The seemingly instant decay of brakes is caused by their over-capacity in most ordinary situations. If you drive like a normal human being, you just don't need much brake. So it's possible to have the brakes worn to a dangerously low level and not know anything about it until it's too late.

The only way to prevent this unfortunate situation is to inspect the brakes regularly. Every 12,000 miles or each year, whichever occurs first, is a good interval for pulling at least one drum and taking a look at what's going on. Pulling all four drums is much better. Whichever you do, you have to know what to look for. So let's start at the beginning and go through the brake system completely.

HYDRAULIC DESIGN

Hydraulics are quite simple and easy to understand, and are based on the simple principle that fluids cannot be compressed like gases. It is therefore possible to move a column of liquid (hydraulic brake fluid) from the actuator or master cylinder, through a pipeline system, to the slave or wheel cylinders, whose movement causes the friction material (brake lining) to come in contact with the wheel driven drum or disc and force it to slow or stop.

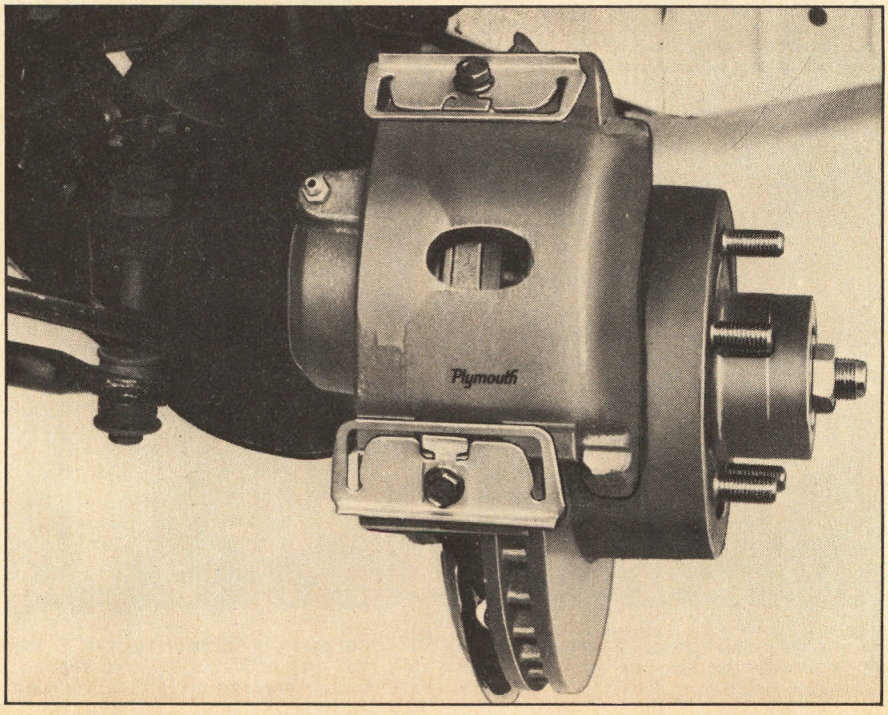
The master cylinder is filled with fluid and has a piston at what might be termed bottom dead center, with the connecting rod linked to the brake pedal itself. Hydraulic lines connect this cylinder with the slave units at the wheels. These are best described as a cylinder with a piston at each end. As the pedal is pressed, the master cylinder piston pushes the fluid through the lines to each wheel cylinder, causing the wheel cylinder pistons to push outward, forcing the brake shoes against the drum. Since this pressure is equal to all wheel cylinders, effective braking pressure cannot be applied to any one wheel until all the shoes on the wheels are in contact with their respective drums, providing a self-equalizing effect.

Drum brake systems are designed so that there is always a little pressure in the line when the brakes are not being used. This pressure is maintained by the check valve, sometimes called a residual pressure valve. The large spring in the master cylinder makes it work, and keeps slight pressure in the lines to hold the wheel cylinder pistons out against the shoe tabs. Without the residual pressure, the pistons might vibrate away from the shoes, which would cause low pedal and lack of brakes. Disc brakes do not use the check valve because their seals fit much tighter, keeping the pistons from vibrating away from the disc. With a disc/drum system, it is necessary to have a check valve in the line to the drum brakes, but not to the disc brakes. In disc/drum systems that have a dual master cylinder, the check valves are in the master cylinder outlet, right where the drum brake line screws on. With a single master cylinder, the check valve has to be further downstream, in the line that feeds the drum brakes.

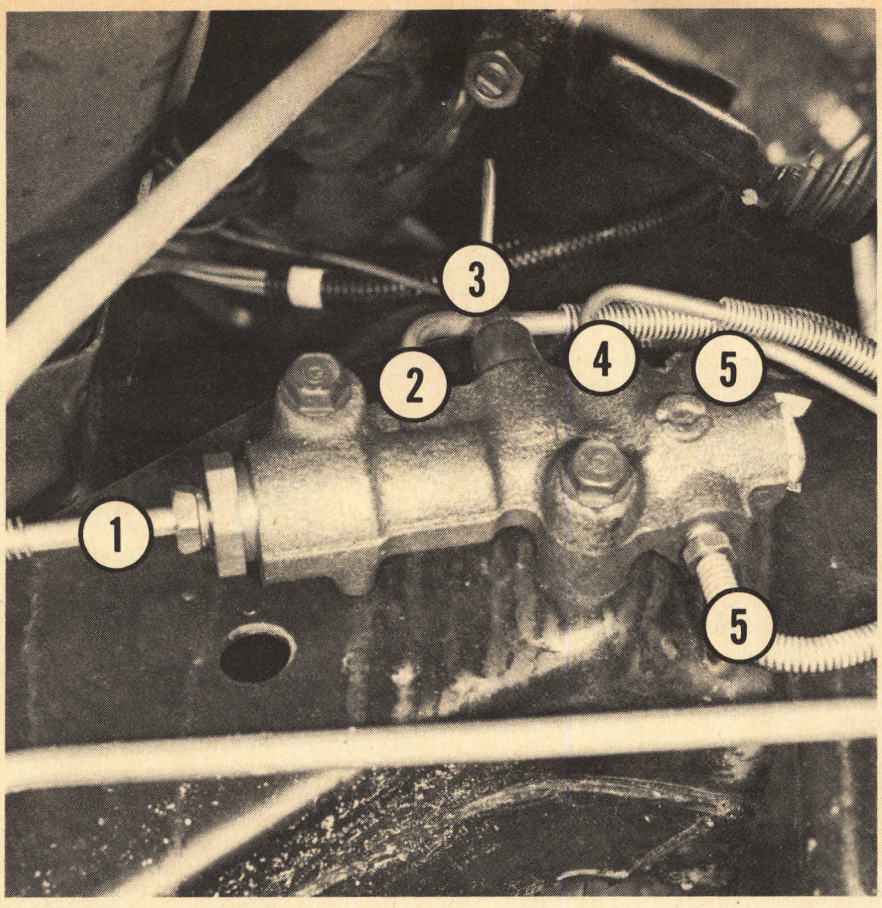
As we said before, liquids cannot be compressed, but gases such as air can be, so it is very important that such a hydraulic system be free of any bubbles of air. Removal of such extraneous air is done by bleeding, an important part of the servicing procedure. To insure that the system is always air free, cup-like seals of rubber or neoprene are used on all master and wheel cylinders, and a fluid supply reservoir is incorporated into the master cylinder. The fluid itself is compounded especially for automotive hydraulic brake systems and should never be mixed with or contaminated by solvents. It will withstand very low temperatures without freezing and very high temperatures without boiling away; it gets sticky on exposure to air and will ruin paint or brake lining material.

In addition to the self-equalizing feature, and the elimination of mechanical linkage from brake pedal to wheels, hydraulic systems can be used to create multiplication of force or leverage. In mechanical leverage, where the length of the lever determines the increase in force (such as the brake pedal itself), the area of the actuating (master cylinder) piston in relation to that of the slave (wheel cylinder) piston determines the amount of hydraulic leverage. In addition to being used to apply the necessary force of shoes against drums, it is also used to compensate for a change of weight distribution under rapid stopping conditions. Here the front wheels are subjected to as high as 75% of the vehicle's weight and, therefore, must exert more braking force without locking the rear wheels. This is done by making the front wheel cylinders slightly larger in piston diameter than the rear cylinder pistons.

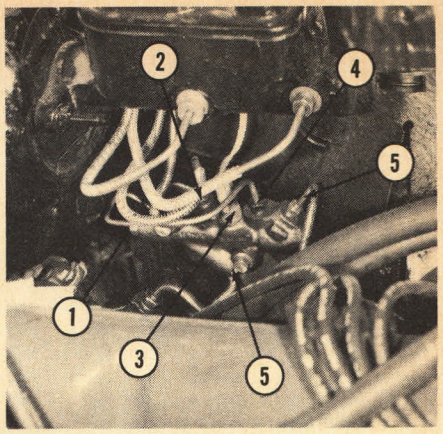
There are tremendous hydraulic pressures involved in the braking system, which is why it's important to be sure that the plumbing and cylinders are free from leaks and bits of dirt or other foreign particles that might disturb the seals, and that the lines themselves are not cracked or fractured in such a way that a sudden surge of pressure will



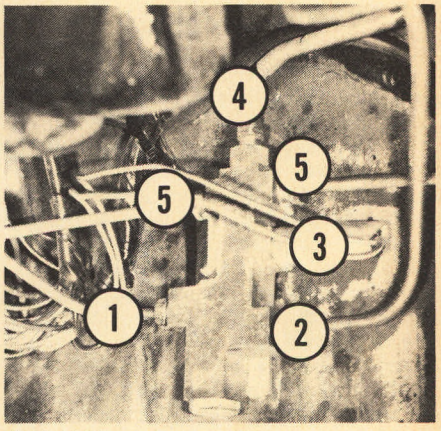
1. Slider Type Disc Brake



2. GM Proportioning Valve



3. Chrysler Proportioning Valve



4. Ford Proportioning Valve

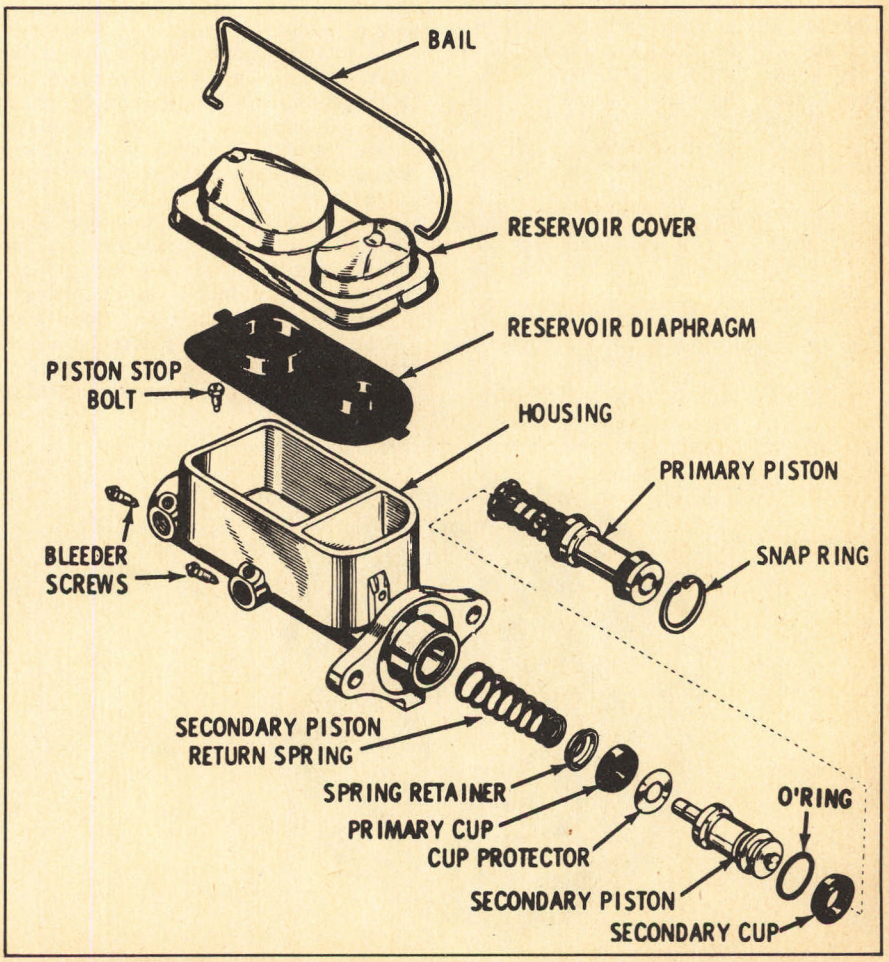
1. Newest design in disc brakes is Chrysler Corporation's slider type—a single-piston floating caliper that slides on the two machined outer surfaces of the disc during application. A 3rd-generation Chrysler disc design, it offers better performance with simpler construction and is standard equipment on all 1973 V-8 models.

2-4. Combination brake warning switch/proportioning valves differ in appearance from car to car, but all have same function: (1) Outlet to rear brakes, (2) from "R" outlet of master cylinder, (3) switch assembly, (4) from "F" outlet of master cylinder, and (5) outlet to front brakes.

5. All late model cars now use a tandem master cylinder to prevent 4-wheel brake failures. You'll find a double hydraulic cylinder.

cause them to break. With a pedal force of 100 lbs.—which is not hard to exert under panic stop conditions—hydraulic line pressure will be anywhere from 800 to 1300 psi (pounds per square inch), depending on mechanical pedal linkage and hydraulic leverage between master and wheel pistons. Power-assisted brakes require less foot pressure but exert the same amount of line pressure.

A part of the hydraulic system on late-model cars with dual master cylinders is the brake failure warning light switch, sometimes called the differential pressure switch. The switch consists of a piston inside a bore with one end connected to the front hydraulic line and the other end connected to the rear line. Normally the piston doesn't move, be-



5. Tandem Master Cylinder

cause hydraulic pressure is equal throughout the system. But if there is a leak in one half of the system, pressure will drop in that half, and the normal pressure in the other half of the system will move the piston in the bore and turn on the light. Some of the switches turn the light on only while your foot is on the brake, while others leave the light on. Late-model switches are made in one piece with the metering valve and proportioning valve. Connecting passages in the one-piece casting eliminate the many lines that looked like a bowl of spaghetti when there were three separate units.

BRAKE DESIGN

All friction-type braking systems are essentially heat systems. Bringing the average-sized car to a maximum effort stop (just short of locking the wheels) from highway cruising speeds generates enough heat in the linings and drums to melt them if it were not dissipated properly. The lining material is very important but it must also be compatible with the drum material, maintaining its coefficient of friction throughout the braking cycle without excessive wear to either lining or drum. Any oil, water, or hydraulic fluid that comes between lining and drum effectively destroys this correct coefficient of friction.

Cooling a conventional drum brake assembly is difficult, and the number of successive high-speed stops is limited to the ability of the brake cooling design to stay ahead of the heat build-up. Cast iron drums, the most commonly used, depend mostly on air passing by them in the rather restricted confines of the wheel recess. Engineers have been improving this airflow by ducting air into the wheel/drum cavity, finning the drums and combining cast iron liners with aluminum drum housings. All for more efficient brakes.

Modern linings also assist in transferring some of the heat, but the necessity of a backing plate makes internal cooling without ducting difficult. In addition to holding the necessary shoe assemblies, the backing plate is designed to minimize entrance of water and abrasive dirt into the critical space between shoe and drum. While moderately effective in keeping small quantities of dust and water out, large doses get through and are retained by the very same shield. The adverse effect of dust and water (especially the latter) on braking efficiency has been virtually eliminated by the caliper disc systems available on the late model cars.

The efficiency of a braking system, in addition to properly conditioned hydraulics, depends on proper lining material of adequate thickness, internally smooth and round drums, maximum contact between lining area and drum surface, and cooling. In addition to the force exerted on the shoes by the mechanical and hydraulic leverage, additional pressure between shoes and drum is achieved by self-energizing where the actual contact of the shoe with the drum is used to apply additional force to the drum. As the brakes are applied, the friction between lining and drum wants to force the shoes around in the direction of drum rotation. The location of the shoe pivot point determines whether the shoe is forced against the drum (self-energizing) or away from the drum by the rotation of the drum itself. Most designs today get additional power by linking the two shoes together so that not only are both shoes self-energizing, but the primary shoe exerts pressure on the secondary shoe, pushing the secondary shoe into the drums that much harder. This is called "servo" action.

Despite the rather long travel of the brake pedal, the wheel cylinders and brake shoes do not move very far to make contact with the drum, mainly because the mechanical and hydraulic leverage necessary for the pressure requirements.

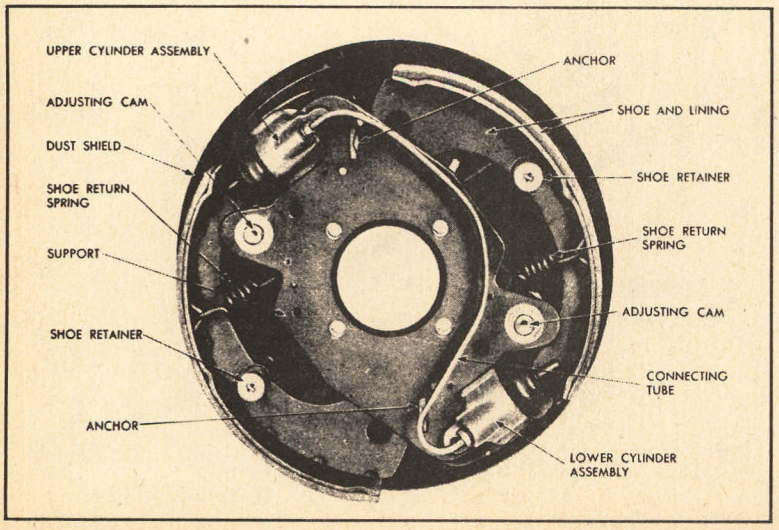
To compensate for lining and drum wear, an adjustment for setting the shoes closer to the drum is incorporated into the brake assembly. In recent years, a self-adjusting feature has been standardized to eliminate the need for a periodic "setting up the shoes" service procedure. In simple terms, self-adjusting linkage uses the rotating shoe action in reverse to operate a lever that picks up an extra notch on the star wheel adjuster nut, if wear allows the shoes to move far enough for the lever to engage. Self-adjusters work only when the brakes are applied while the vehicle is moving backwards. They do not compensate for drum expansion caused by heat. If you back up when your brakes are hot, the automatic adjustment can cause the rear shoes to drag when the drums cool off.

ROAD TEST ANALYSIS

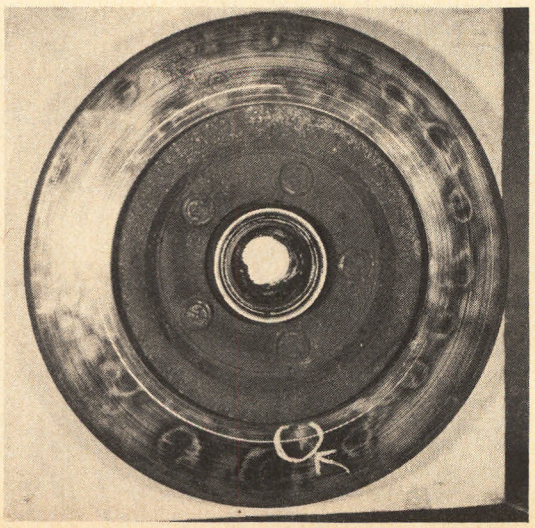
Before beginning any type of brake service or overhaul, it is best to determine by actual road test just what might be required. Select a smooth, paved, dry section of street or road free of traffic or other obstacles. At a speed of 20 mph, apply the brakes firmly for as rapid a stop as possible without locking the wheels. If the pedal depresses to within 2 ins. or less of the floorboard, the linings are badly worn, brake fluid level is low, or the shoes need adjusting. A spongy feeling to the pedal indicates air in the system (except on some disc brakes, which are designed that way). With the car at rest, press brake pedal as hard as possible, holding it down firmly to note whether it continues to move slowly downward. Any such movement indicates poor sealing master or wheel cylinders or a leak somewhere in the plumbing system.

Should the car pull to one side or the other, or if one wheel grabs, it is an indication of several possible problems: improper adjustment, grease or hydraulic fluid on the linings, loose backing plate, reversed primary and secondary shoes, brake shoes not properly arced to drum resulting in partial contact, plugged master cylinder relief valve, poor pedal linkage adjustment, or an out-of-round drum. While conducting these rolling brake tests, listen for grinding or rubbing noises with brakes off and applied. Rubbing sounds without brake application indicates improper initial adjustment, faulty or broken return spring, binding wheel cylinder or shoe guides.

Grinding or squeaks when the brakes are applied can mean brake linings worn



1. Leading-Shoe Brake



2. Cracked Brake Rotor

1. There is no servo-action in a leading-shoe brake, but each brake shoe is self-energizing. Late model cars favor the servo-action design.

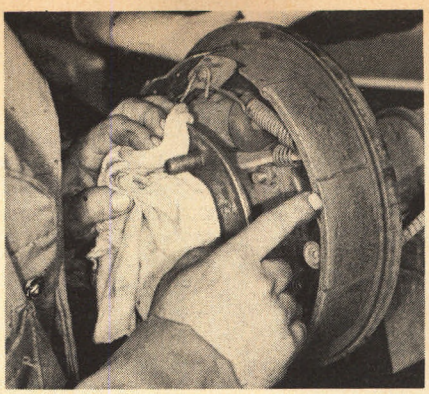
2. Chalk-marked area has crack in brake disc, rendering it unsafe for use. Discs should be checked for such failures every time pads are changed.

3. Velvetouch Metalik brake linings are latest wrinkle for the performance-minded. Since linings were almost as good as new two years after installation, there's something here for the economy-minded also.

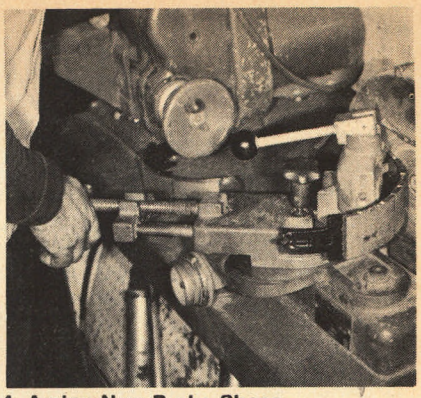
4. There are pros and cons on arcing new brake shoes before installing them, but many brake specialists wouldn't think of a brake job without this.

5. Velvetouch Metalik disc linings should be chamfered at each end before use. As lining material is soft metal, there's a certain amount of residue caused by braking action, and this creates a place for it to go.

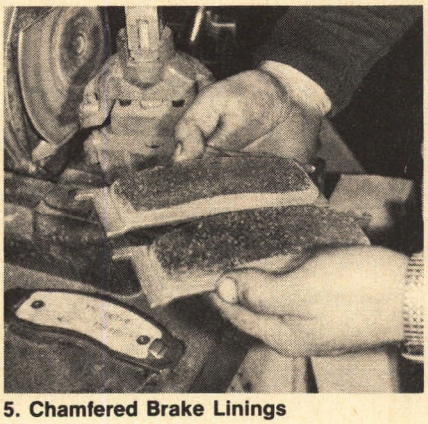
6. Metalik brake installation is very similar to that of ordinary organic lining, except that starwheel adjuster is not connected to self-adjusting lever. By themselves, there's very little wear; adjustment every 6-9 months will do. Self-adjusters will cause constant drag on linings and wear them down fast. Use heavy-duty shoe return and hold-down springs, too.



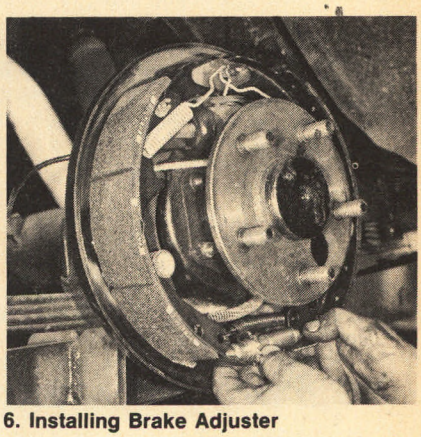
3. Metalik Brake Lining



4. Arcing New Brake Shoes



5. Chamfered Brake Linings



6. Installing Brake Adjuster

to rivets or shoes, dust in rivet holes, improper lining material, oil or grease on linings, or warped backing plates. Faulty front wheel bearings can also affect braking efficiency and cause a lot of unnecessary searching for defect in the brake assembly if they are not checked during the overhaul. Don't get carried away setting up the mechanical linkage for the parking brake, as drag here can ruin a set of rear brake assemblies.

For cars equipped with power assists—either the booster type used on Ford and Chrysler products, or the combined unit featured on GM cars—there is a simple drive test to determine faults in this area that may save unnecessary tearing into the entire system.

With the engine off and the transmission in neutral, press the brake pedal several times which will bleed off the vacuum reserve in the reservoir. Apply a light pressure to the pedal, depressing it just beyond taking up any slack in the linkage, and hold it there lightly while starting the engine. As the engine starts, the pedal will feel like it is dropping away underfoot, requiring less pressure and indicating that the assist system is working. If there is no action, the fault can be assumed to be in the power assist unit.

Again with the engine off, deplete the vacuum reserve as before, then start the engine, run at fast idle for a few moments, then stop engine with throttle closed. Wait for about 2 mins. and try the brake again. There should be enough vacuum reserve in the system for several assisted braking efforts. If there is no such reaction, the cause can be isolated to a faulty vacuum check valve.

RELINING

It is not likely that the home repair enthusiast will have all the equipment necessary for machining drums, relining shoes, or arcing them to conform to the drum diameter. Therefore, the car should be jacked and placed on suitable stands so that all four wheel assemblies can be removed at the same time.

Select a level surface for this jacking operation, preferably a paved one to insure sturdy jack stand foundation and to reduce the possibility of extraneous dirt entering the system. The ideal equipment for this operation is a regular hydraulic floor jack and four jack stands. Remove wheel covers, loosen wheel stud nuts, and with the rear wheels blocked, raise the front end just enough for the tires to clear the ground by jacking in the center of the front crossmember. Place a jack stand under each lower suspension arm as close as possible to the inside of wheel and tire but not interfering with their removal, then lower jack slowly so front end is resting securely on stands. Raise the rear wheels by jacking at the differential, placing jack stands under axle housing carefully so as not to endanger any hydraulic lines that may be strung along this housing.

In lieu of such professional jacking equipment, a bumper jack and a quantity of short pieces of lumber, preferably 2×4's about 12 ins. long, can be used very well to raise and hold the car safely off its wheels for brake servicing. With the rear wheels well blocked to prevent rolling, begin by bumper jacking each front wheel separately, just as you would to change atire. Using the short pieces of lumber, build a stand under the front suspension by placing the wood pieces log cabin style to the required height. Lower the car and repeat for each wheel. Don't use rotted lumber or skinny pieces on end and expect it to safely support your car. Avoid orange crates or boxes which can collapse and not only injure you, but also damage the car.

A friend with access to a frame-type grease lift in a garage or service station, who is willing to allow it to be tied up long enough to do all of the wheel work in connection with a brake line/drum grind operation, can be a great asset and solve all of the jacking and jack stand problems.

REMOVING WHEELS AND DRUMS

Whatever jacking system is used, the next step is to remove the wheels and then the drums. Begin with the front ones, as in most cases except later model GM cars, the wheel hub is part of the brake drum, and front drum bearings, seals and lubricant. Once the cotter pin is freed of the axle nut, carefully remove nut and washers. The brake shoes may have to be backed off at this point to allow the drum to be wiggled off. The star wheel, similar to a coarse-toothed gear, is located at the bottom of the shoe assembly and is accessible through a slot in the drum.

Some cars like early Lincoln and Mercury have the slot in the backing plate covered by a pop-out plate. If the car has self-adjusting brakes, the adjusting lever must be held out of the way while the star wheel is turned. This means inserting two tools—a thin screwdriver to hold the lever up, and a brake adjusting tool—into the slot at the same time. Follow the same procedure for backing off

on rear shoes prior to drum removal, if necessary.

It is a good idea to mark the drums and shoes so that each complete assembly can be returned after servicing to the original wheel position. Keeping them in paired sets will save a lot of reassembly time. The marking should include identity for forward and reverse shoes on each wheel. Scratching with a sharp instrument or center punching with a series of coded dots is a good method.

Remove drums, taking care to protect front wheel bearings and seals from dust and dirt. Examine backing plate for presence of wheel cylinder stop plate. Late-model cars have these stops to prevent wheel cylinders from popping out when shoes are removed, as there is always a slight static hydraulic pressure in a well working brake system. If there is no stop plate, a wheel cylinder clamp will be required to hold the cylinders in position while shoes are removed. Under no conditions should the brake pedal be depressed while the drums are removed.

Before proceeding further, study the indicated illustrations to be sure of the identity and functions of the internal brake parts. The brake shoes can now be removed by detaching the shoe hold-down discs, springs and pins, and then the return springs from the anchor pin. In shop practice, this latter operation is done with a special tool but can be accomplished by grasping the long shank of the spring firmly with vise-grip pliers, stretching the spring sufficiently to remove it from the anchor pin. On rear brakes where the parking brake operates on the rear shoe only, disconnect the parking brake cable and remove parking brake strut and lever. Final removal of the shoes front and rear on single anchor brakes, is done by spreading them to clear the wheel cylinder connecting links, whereupon both shoes will come off as a unit, still held together by the adjustment screw and spring.

Total-contact brakes, used on earlier Chrysler products, have a slightly different hold-down and return-spring arrangement, and a special tool is required to prevent damage to the shoes. With guide springs, retainers and return springs removed, further dismantling is the same as with conventional assemblies.

CLEANING AND INSPECTION

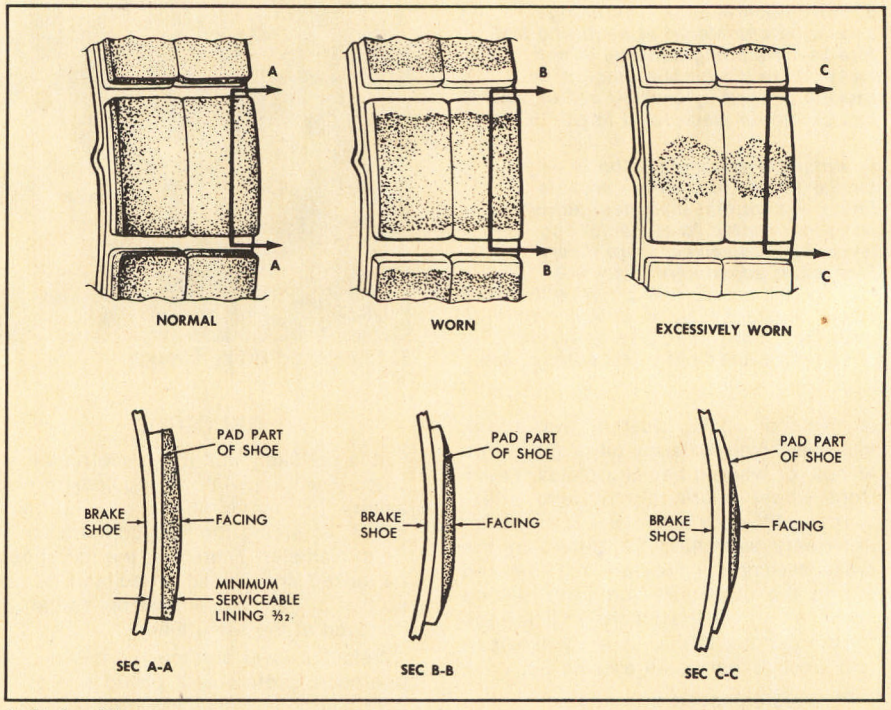
Now is the time to clean and inspect the brakes, and while they are removed, the front wheel bearings. If air pressure is available, use it to clean drum dust from all parts, being careful not to blow it into wheel bearing assembly. A stiff brush is a good substitute for compressed air. If very dirty, wash drum, backing plate, and metal part of shoes in clean solvent and dry thoroughly. Be careful to keep the solvent away from cylinder boots and brake lining. Check for pits or dark spots on the bearing races and plan to replace before reassembly if bearing wear is indicated. Check for oil leaks around the rear wheel bearings and replace seal if indicated; seepage here can spoil a good brake job very quickly.

Check all wheel cylinders for piston leaks by carefully lifting each boot to note if interior is wet with brake fluid. If so, the wheel cylinders must be overhauled or replaced (this procedure is discussed later in this chapter).

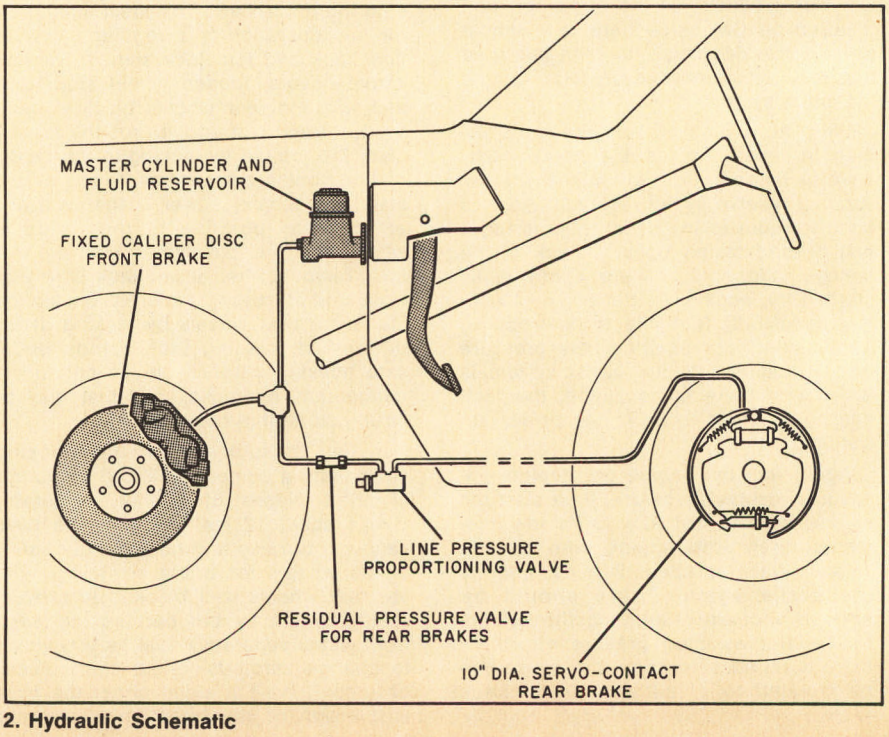
Examine the linings and drums for wear and grooving, to see if braking problems might be caused by other than normal wear. The lining should show evidence of uniform wear both along its contact arc and across it. Thin spots in the center of the shoes are normal with oversize drums, because the shoe radius and drum radius are not the same. Thinner edges side-to-side show that the shoes have been canted by bent backing plates or anchor pins.

DRUM TURNING

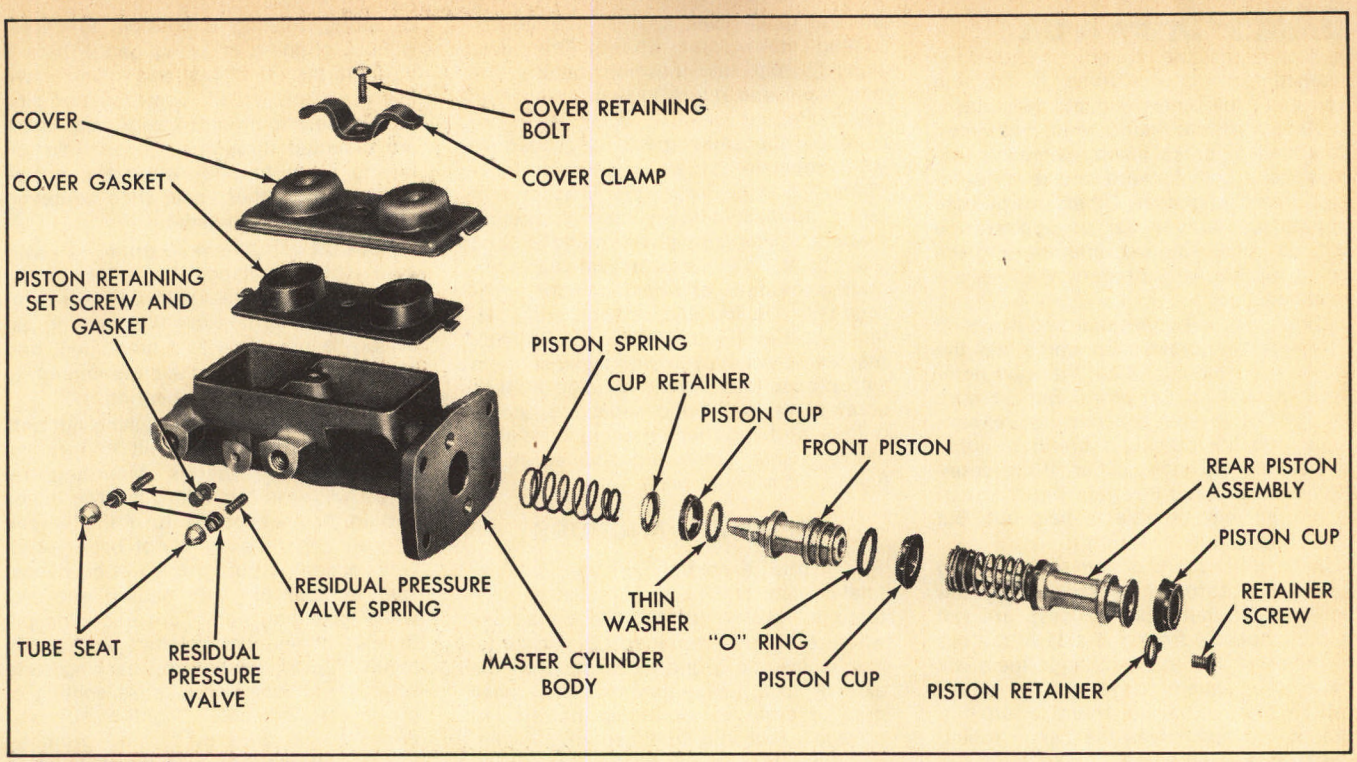
Most drums, after periods of normal use, become out-of-round and almost always grooved from the abrasive action of dust and dirt between linings and drum. Drums can be restored by machining or grinding on special drum lathes, and it is safe to remove as much as .030-in. of material to bring them back to normal roundness and smoothness. This means that the internal drum diameter will be increased by .060-in. and the relined shoes must be altered to conform to the new diameter. This is done by use



1. Lining Wear



2. Hydraulic Schematic



3. Disassembled Master Cylinder

1. These illustrations show brake linings in different stages of wear. Once the linings get down near the steel brake shoe or pad, it's time to replace the linings. If they aren't changed, then your drums will be ruined, costing you more money, maybe your life if they fail.

2. The proportioning valve limits the pressure to the rear brakes to prevent them from locking up. Also in most disc brake systems, but not shown here, is a metering valve which delays the application of the front brakes until the rear brake shoes have had a chance to expand against the drum, thus helping to equalize brake action.

3. If this master cylinder were on a car with disc brakes, the outlet to the disc brakes would not have a check valve, but it would have a tube seat insert.

of oversize lining or shimming standard lining, then arc grinding to conform to the new drum diameter.

LINING MATERIALS

Modern brake lining materials—that used generally for the past 10 to 15 years—is molded, then bonded or riveted to the shoes to insure positive contact and maintenance of constant curve and to prevent shifting or coming off the shoe. Equipment for relining, drum grinding, and shoe-to-drum matching is not only expensive, but requires training for proper use. These factors alone make it impractical for an amateur mechanic to own things as drum grinders, arcing jigs, and a stock of lining material, rivets, and bonding ovens.

Brake lining can be purchased in several ways. Professional brake servicing companies use rolls of material that must be cut to size, drilled and countersunk for rivets, beveled, and fitted to the shoes. Precut and drilled linings are available to fit specific car models, and replacement shoes, completely lined and ready to install, can be purchased from brake supply houses and new-car service departments. All forms are available in oversize thickness to compensate for drum grinding, as is shim stock for use under standard lining material, although oversize lining is the usual method. Premium lining materials, such as sintered metallic and a wide variety of various degrees of hardness for specific purposes, are available as replacements for standard material. Brake supply houses which handle name-brand items will have specifications for just about any car made, and following their recommendations will provide the right lining for the indicated purpose.

As with riveted linings, bonded materials require special skills and equipment to replace. Old linings must be chiseled or burned off the shoes, which are then carefully sanded in preparation for the liquid cement or special tape adhesive. Cemented shoe assemblies are then clamped in a special jig that applies high, even pressure and heat over the entire contact surface to insure adequate bond. It is obvious that the home brake repairman who purchases relined shoes properly arced to his professionally ground drums is getting a better and lower cost job than he could possibly do himself.

REINSTALLING SHOES AND DRUMS

Installing the relined shoes and matching drums must be done with great care and cleanliness. Avoid touching linings or drums with greasy hands, and allow no hydraulic fluid to come in contact with the lining material. If the shoes and drums have been kept separated in matching sets as previously suggested, prepare to assemble each to its matching wheel.

While it is readily accessible, the adjusting screw assembly should be dismantled, cleaned in solvent, dried, and lubricated before reassembly. The inboard side of the backing plate should also be cleaned of road grime; this will ease locating the cylinder bleeder valve and anchor pin adjustment, if there is one.

Proper lubrication of all brake friction points is necessary for long trouble-free operation. For this purpose, a special compound brake grease is used. It has properties just for this application that prevent it from running or vaporizing under the heat of severe brake application so that it may be safely used without fear of getting into the drum/lining contact area. However, it should be used sparingly when the adjusting screw mechanism is assembled and at all mechanical contact points between shoes and backing plate. On rear brakes be sure to lubricate the parking brake cable assembly.

If the system has a self-adjusting mechanism, this should be assembled and lubricated prior to the installation of shoes. In any case, the star wheel adjusting nut must be centered over the backing plate slot (if this type of accessibility is provided) or centered to afford proper adjusting movement (if this is done through an opening in the drum itself). As these adjusting assemblies are not interchangeable with the opposite wheels, care must be taken to keep the parts for each wheel exclusively for that wheel.

Place shoes on backing plate, engaging them with the anchor pin and the wheel cylinder connecting links. Be sure the shoes are in proper relative position. Usually the forward has the short lining, but not always. The shoes should be

marked forward or reverse. If not, and you can't tell by looking at them, ask a professional mechanic who has used that kind of brake lining. Some companies make both forward and reverse linings interchangeable. Others make both linings identical as far as appearance but the composition is different, and the lining will not work properly if shoes are reversed.

Don't feel self-conscious about asking a professional brake man which way the shoes go. It is a problem that has bothered mechanics for years. But be sure the mechanic you ask has had experience with the particular brand of lining or he may not know, either. If the counterman where you buy your parts is really hip, he may be able to help out. But don't necessarily count on it.

If the brakes are of the self-adjusting type, take care when assembling the self-adjuster mechanism. These are not interchangeable from one side of the car to the other and to interchange them will cause the adjuster to retract the shoes rather than advance them when the brakes are applied as the car is rolling backwards. Remember, make sure the parts are not binding on their anchor pin and that both shoe return springs are installed over the adjuster anchor fitting.

Adjusting screws for self-adjusting brakes are assembled with the thread screwed all the way in and then backed off about one turn. The star wheel is positioned toward the rear or secondary shoe, and the self-adjusting actuating lever is spring-linked to the primary shoe and cable- or rod-linked to top anchor pin. Before proceeding further, check operation of self-adjuster by pulling on cable or link toward secondary shoe just enough to lift lever past a tooth in adjusting screw star wheel. The lever should snap into position behind the next tooth and return to original position when released.

Follow the same greasing procedure when replacing shoes on Chrysler total-contact brakes. Insert the long end of return springs in the shoe web (before placing shoes into position) by sliding them between the support plates and engaging the ends of wheel cylinder pushrods with the toe end of each shoe. Attach short end of return springs to their respective links by prying against them with proper tool. A long-handled Phillips screwdriver is a good substitute. Install guides and retainers making sure that the little lip or guide is positioned in the hole in the support plate.

ADJUSTING ANCHORS

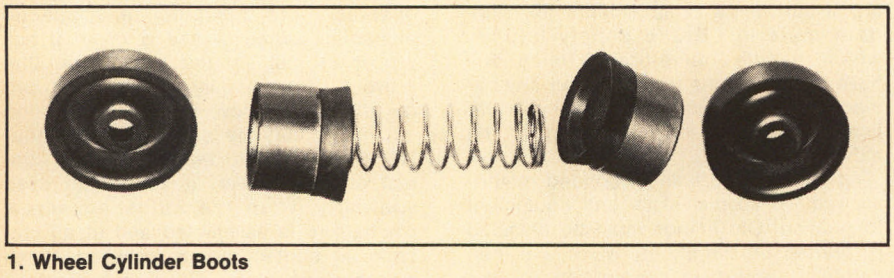
With the exception of the Chrysler total-contact brakes, shoes must be centered in relation to the axle center-line when they are replaced. Professional mechanics use a grinder pivoting on the axle or axle flange for removing small precise amounts of lining material to provide exact and true centering of lining diameters in relation to the drum. Another method is to use a gauge bar pivoting on the axle to determine just how far off center the shoes are and in what direction. Early Chrysler brakes have eccentric anchors at the bottom which allow the shoes to be shifted to the proper position, and the gauge is necessary for this operation. By setting the gauge bar to the drum diameter and the indicated calibrations for proper clearance, the eccentrics are adjusted while checking with the gauge bar.

Early Bendix-type brakes employ two types of anchor pin adjustments for shoe centering, making it possible to center without grinding or using gauge bars if the refurbished shoes and drums have been properly arced. Some anchor pins have eccentric threaded ends and others are mounted through a slotted hole, allowing them to shift when the nut is loosened. In either case, shoe centering procedures are the same.

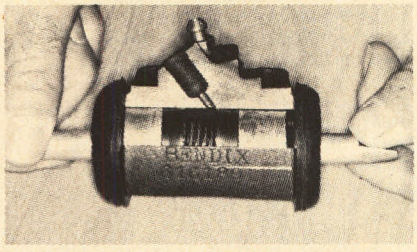
Back off adjustment so drums fit easily onto mounting flanges or axles. In the case of front wheels with bearings integral with drum, be sure that bearing assembly is complete and lubricated, and that wheel bearing nut is snug enough to prevent any play in the bearing.

Turn the brake shoe adjusting nut until maximum effort is required to turn the drum with both hands. Mounting the wheel will ease this effort, but two hands should be needed to turn the wheel. Loosen anchor pin nut not over ¾-turn (with eccentric pin type it will be necessary to hold pin with square end tool while loosening nut). Turn eccentric pin to shift shoes. With slotted anchor pin mount, loosen nut and rap backing plate smartly with hammer to ease shifting of pin in slotted hole. Tighten nut and check brake drag by turning drum by hand, noticing any difference in drag from the initial setting. If drag is the same, the shoes are properly centered. If drag decreases, it indicates the anchor pin has shifted. Repeat by again setting brake adjusted nut to hard two-handed drag and effecting further shoe shifting by either turning eccentric or loosening anchor pin nut and then tapping the backing plate with a hammer.

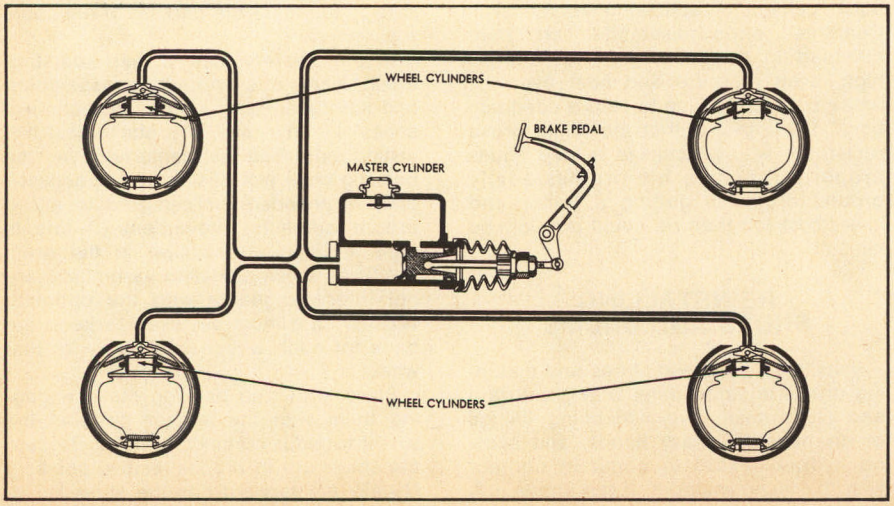
Some cars use a nonadjustable anchor and if the lining and drums are standard it works fine, but when you go into oversizes there is a problem in getting the shoes centered. Some exchange shoes



1. Wheel Cylinder Boots



2. Wheel Cylinder Cutaway

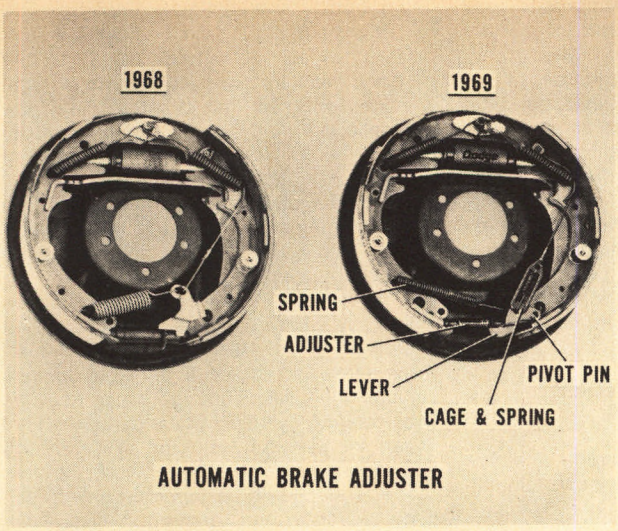


3. Hydraulic System Schematic

1. The end components here are press-on boots that cover the ends of wheel cylinders. Next are the metal pistons, which actuate the pushrods, thence the shoes. On the inside, separated by the coil spring, are the piston cups. The hydraulic fluid in the wheel cylinder is in this area, between the cups.

2. This cutaway cylinder reveals the boots on the ends, the pistons and pushrods (held in hand), the piston cups and spring. Fluid enters the cylinder via threaded opening, forcing the cups and pistons out, actuating the brakes.

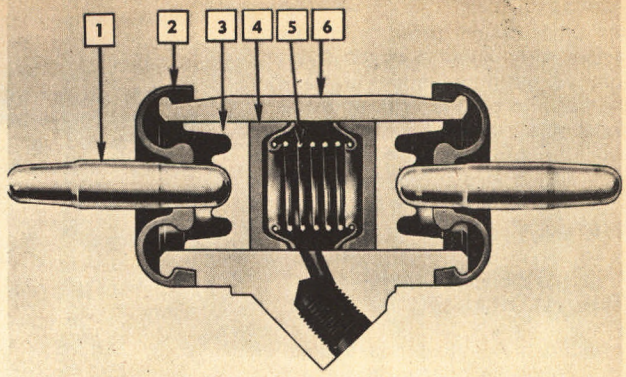
3. Equal hydraulic pressure does not guarantee equal braking effort on each wheel. If the type of lining or metal in one drum differs from others, brakes may pull to one side.



AUTOMATIC BRAKE ADJUSTER

4. Automatic Brake Adjuster

4. The automatic brake adjuster on '69 Dodges reduces possibility of over-adjustment, takes place when backing, with brakes applied.



1. Link
2. Boot
3. Piston
4. Rubber Cup
5. Return Spring
6. Wheel Cylinder

5. Wheel Cylinder Parts

5. This illustration shows the components of a wheel cylinder.

have the anchor hole relocated so that they fit properly. Otherwise the lining must be arced off center in a special jig that fits on the shoe grinder.

ADJUSTING SHOES

Whether late-model, self-adjusting brakes or older manual models are relined, an initial adjustment is required for proper operation. After the shoe centering operation on new brakes, or to correct for normal lining wear and to raise effective brake pedal, a minor brake adjustment is necessary to provide proper clearance between lining and drum. For brakes without self-adjusters, this is best done with all four wheels off the ground. Using a suitable tool through the backing plate or drum slot provided, turn adjusting wheel so there is a slight drag as the wheel is turned. Repeat with each wheel, trying for the same amount of drag. Then, back off an equal number of notches on the adjuster at each wheel—12 to 15 notches are average—making sure that there is no drag. If any is detected, back off an additional one or two notches on that wheel. Apply brake pedal firmly several times and check for drag again.

Bleed the hydraulic system (see details below) and make several slow speed stops to check equal braking. With self-adjusting brakes, centering procedures are the same and setting shoe-to-drum clearance is not as critical. Just be sure that the shoe adjusting screw for each wheel is backed off enough to clear shoes from any detectable drag, then achieve final adjustment by applying brakes while car is moving in reverse which will activate the self-adjuster and bring the shoes to proper clearance.

BLEEDING THE HYDRAULIC SYSTEM

Following any brake reline job, it is just good business to bleed the system, eliminating any air that may have entered. The idea behind bleeding is to drive any air out of the master cylinder, lines and wheel cylinders, out through special bleeding valves on each wheel cylinder. These are small fittings that look very much like Zerk grease nipples and are located on the backing plate directly behind the wheel cylinder. Unscrewing them slightly opens their passage into the wheel cylinder; it works like a small faucet with a ball-like end on it. As these bleeder valves are usually covered with road grime, they should be cleaned thoroughly for easy access and operation.

Make sure that the master cylinder reservoir is filled and that a supply of new, clean, hydraulic fluid of the proper specification is available to top this level off as the fluid level drops, depending on the amount of bleeding necessary. Pressure bleeding, used by professional brake mechanics, involves the use of a large reservoir of pressurized hydraulic fluid coupled to the system at the master cylinder, and supplying a flow of fluid through all the lines while each wheel cylinder bleeder valve is opened. However, bleeding can be done without this aid by having two people do the job—one to operate the foot pedal, the other to bleed each wheel cylinder.

For bleeding by the two-man method, a bleeding tube and a glass jar or bottle are required. The tube can be procured at any auto supply store and should be long enough to reach from the bleeder ball end to the bottom of the glass jar when it is setting on the ground. Put about 1 in. of clean hydraulic fluid into the jar, slip one end of the bleeder tube onto the bleeder valve, the other into the jar so that it is submerged in the fluid. Open the bleeder valve about ¾-turn and at the same time have the assistant press the brake pedal slowly a full stroke. Close bleeder valve just before brake pedal hits bottom and allow pedal to return slowly to full-out position. Repeat until expelled fluid flows in a solid stream with no presence of air bubbles. Tighten bleeder valve and remove hose. Be sure to constanly check fluid level in master cylinder and top up with new clean fluid only.

With careful work it is possible for one man to bleed brakes with the bleeder hose method. Just be sure the end of the hose is below the surface of the fluid in the jar. Open the bleeder fitting, then go to the pedal and stroke it easily once or twice using about ¾ of the full stroke. Replenish the fluid in the master cylinder, then go to the wheel and close the bleeder fitting. Repeat at each wheel. If the lines are empty it may be necessary to run as much as a cupful of fluid through each cylinder to get all the air out. This would require several strokes of the pedal for each cylinder.

The best procedure is to follow a wheel-to-wheel sequence beginning with the one closest to the master cylinder. This applies to caliper disc units and to later model cars with dual master cylinders. Begin with the left front, then do the right front, left rear, and right rear. This procedure minimizes the possibility of trapped air entering lines already bled. Under no conditions must the master cylinder be emptied during the bleeding process as this pumps air into the system.

WARNING LIGHT SWITCH BLEEDING PROBLEMS

The warning light switch is designed to turn the light on whenever there is a leak. This includes the "leak" you create when you open a bleeder fitting. If the switch is the type that only turns the light on when your foot is on the brake, then no special procedure is required. But if the light stays on after you take your foot off the brake, it means you have the type of switch that must be centered after bleeding. The design of the switch allows pressure from the non-leaking system to move the piston toward the leaking system. If the light is on, you must create a leak by opening a bleeder fitting on the other system. Then you step on the brake pedal gently until the light goes out; close the bleeder fitting and you're done. That's the way the book says to do it, and we wish it was that easy. When you step on the pedal, the light will go out, but the piston keeps moving toward the other side, and puts the light on again. Then you have to close the bleeder fitting, open the fitting

on the other system (front or rear) and try again. After about a dozen trys you will get just the right amount of pressure on the pedal to get the light off. To eliminate all this monkey motion, you can buy a little threaded stud that screws into the switch in place of the electrical connection and holds the piston in the centered position during bleeding.

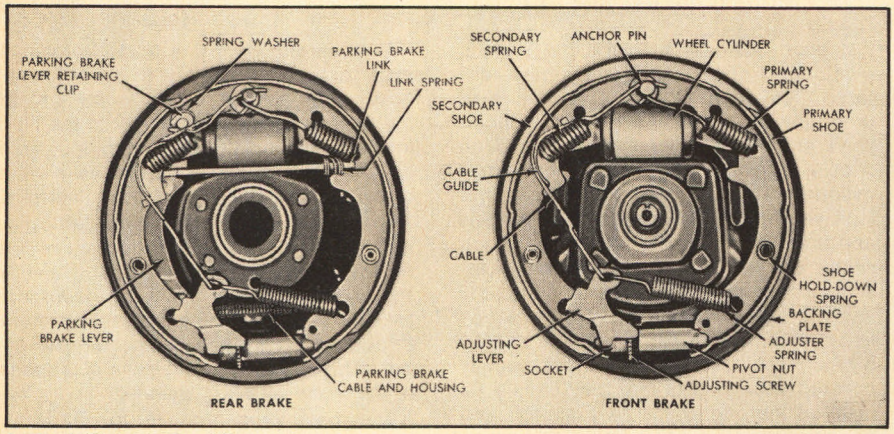
OVERHAULING THE HYDRAULIC SYSTEM

Hydraulic brake fluid has a distinct, sharp, alcohol-like odor in its fresh fluid state and becomes sticky upon prolonged exposure to air, making it pretty easy to identify should leaks develop in lines, master or wheel cylinders. Check all lines from master cylinder to each individual wheel, examining any grime-coated wet spots for evidence of hydraulic fluid. Should any lines need replacing, do not attempt to save any of the fluid for re-use as it may become contaminated and cause damage to the system. Use only steel brake line tubing, properly flared for the fittings. The flexible lines from tubing terminus to wheels are armored for maximum protection and should be replaced only with stock replacement parts for optimum service and safety.

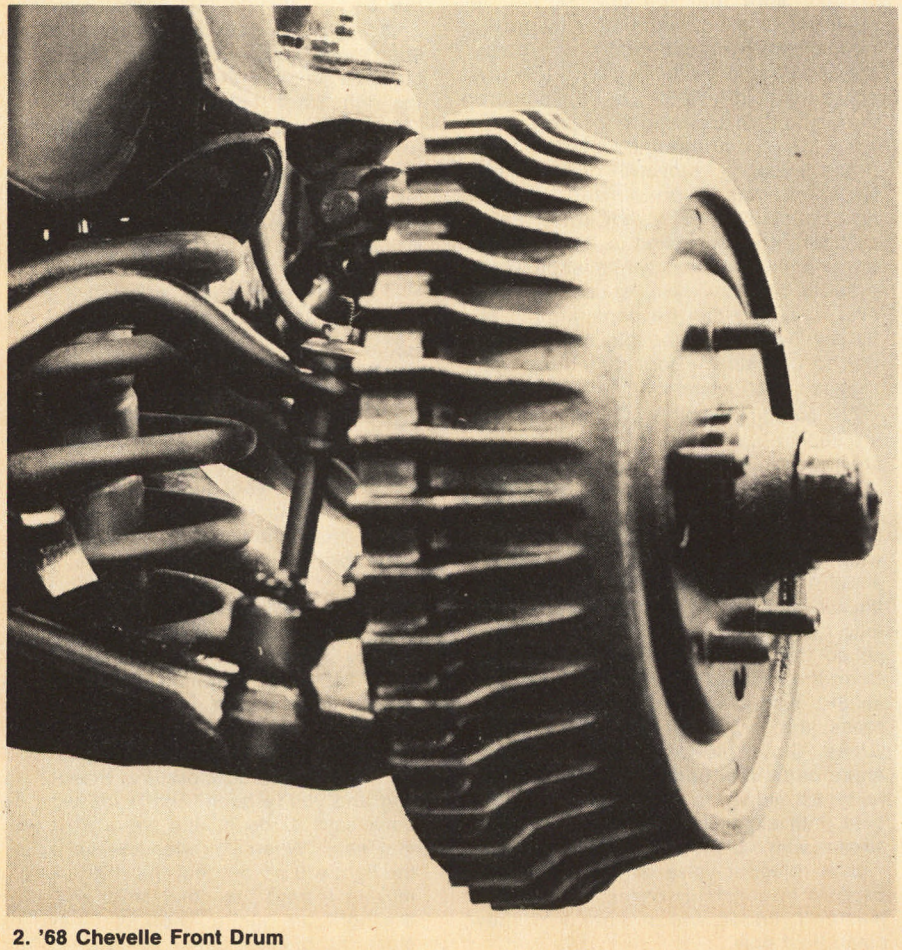
WHEEL CYLINDER OVERHAUL

With the drums removed, examine wheel cylinders for leaks by carefully lifting boots from cylinder housing. Evidence of hydraulic fluid under the boot indicates a bad wheel cylinder, and shoes must be removed before attempting to work on that cylinder. Note: Hydraulic fluid will ruin automotive paint finishes and lining material. All parts of the system activated by hydraulic fluid should be cleaned only with alcohol or special fluids compounded for this purpose and available at automotive parts supply houses.

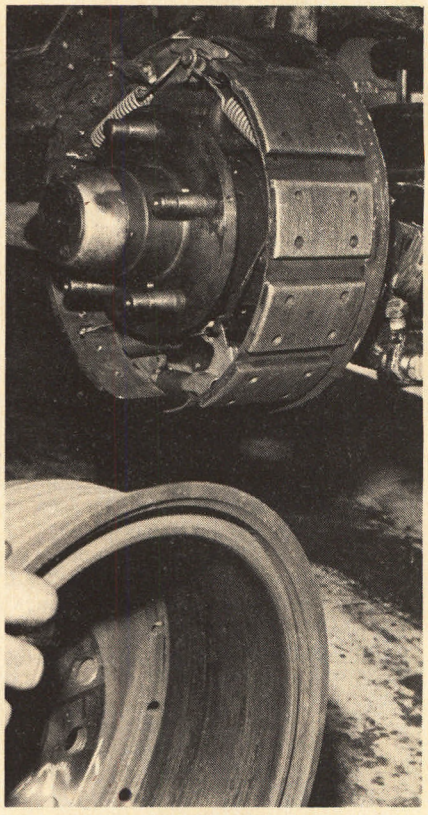
To remove the wheel cylinder, loosen flex line where it connects to cylinder at backing plate. Remove cylinder mounting screws, detach cylinder from backing plate, then finish uncoupling of flex line by rotating cylinder. Some hydraulic fluid can be saved by placing a well-fitting wooden plug into the end of the flex line. This should be tappered slightly but not driven in hard enough to distort line and cause a problem when reassembling is done.



1. Ford/Bendex Dual Servo



2. '68 Chevelle Front Drum



3. Riveted Metallic Linings

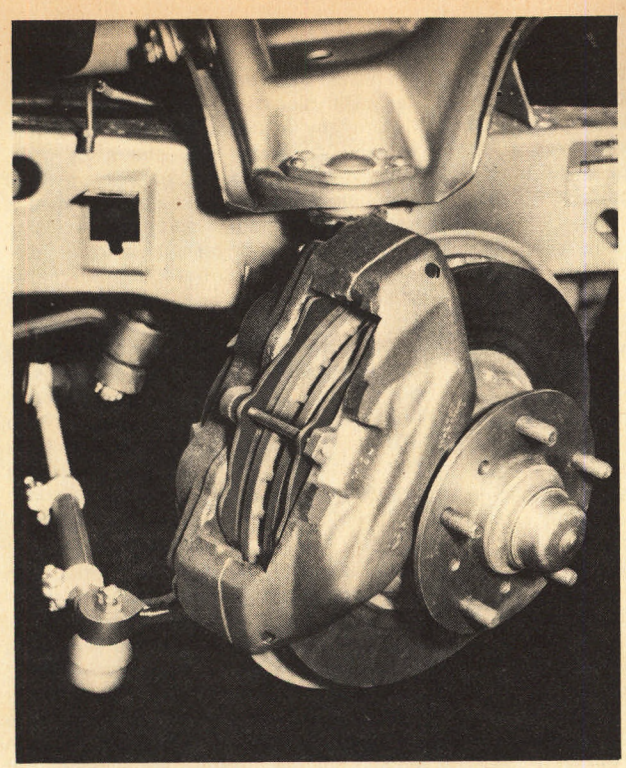
1. A servo-action brake is one in which one shoe pushes on the other, giving the greatest braking action to the second shoe.

2. Front brake drums on '68 Chevelle are finned for improved cooling.

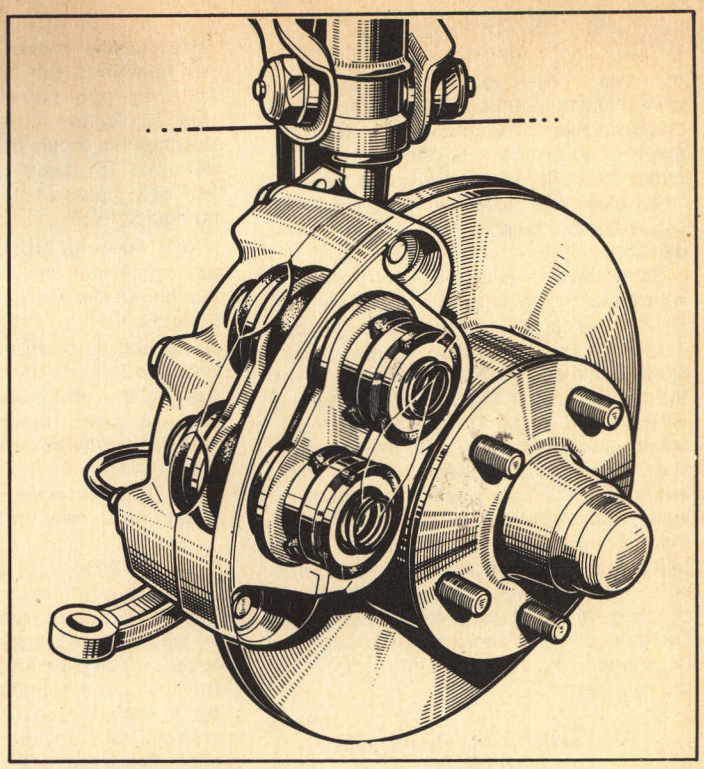
3. This NASCAR stocker features a super-size set of brakes. Riveted metallic linings are segmented so they dissipate heat more quickly.

4. Increased use of disc brakes on American-built cars is a boon to safety enthusiasts. Cars with discs stop faster and suffer less fade.

5. This power disc brake system is found on the Marlin, a former AMC car. Four pistons provide plenty of surface area for the linings.



4. Typical Disc Brake



5. Power Disc Brake

Remove boots, springs, pistons and cups from cylinder and place in alcohol or brake parts cleaning fluid. Clean cylinder casting inside and out, but do not let it soak in fluid. Examine bore for scoring and pitting, and cups for swelling. Scored cylinders can be honed to restore the desired mirror finish but no more than .005-in. may be removed. If more is required, the entire cylinder must be replaced. Replacement kits containing all necessary parts for rebuilding wheel cylinders are readily available from parts houses, and all parts should be replaced while the cylinder is apart; a minor attempt at saving here might result in more expensive repairs later.

If the cups are swollen or mushy, it is an indication that the hydraulic fluid has become contaminated with oil, kerosene, or gasoline. Should this condition be evident, the entire system must be flushed and all wheel and master cylinder cups (and in severe cases, the rubber flex lines), must be replaced. Flushing procedures are covered later in this chapter.

Assembly of wheel cylinders must be carried out under clean conditions, free from possible contamination by dirt, oil, water and solvents, or even dirty or greasy hands. With the finger, coat inside of wheel cylinder wall, as well as piston and cups, with clean hydraulic fluid. Assemble carefully in proper sequence for each side, ending with the boots on the ends. Clean end fitting of flex line and screw cylinder onto line by rotating cylinder until snug. Place cylinder in position on backing plate. Secure cylinder to backing plate with mounting screws and complete tightening of flex line. Repeat for each wheel.

MASTER CYLINDER OVERHAUL

Master cylinders fail and require rebuilding for the same reasons as wheel cylinders. Normal wear, contaminated fluid, and dust and dirt entering the system will eventually spoil the sealing and pumping action. Single master cylinders have a piston and sealing cup actuated by the pedal linkage, a boot to protect pedal rod extension, a check valve, a spring and two small holes in the cylinder wall—a compensating port and a breather—connected to the integral fluid reservoir.

When the pedal is pressed, the piston forces hydraulic fluid through the lines, actuating the wheel cylinders. When the pedal is released, it takes a little longer for the fluid to catch up with the piston, creating a pressure differential between piston and primary cup. Fluid from the integral reservoir flows into the cylinder chamber behind the piston and rushes past the primary piston cup to equal the pressure in front of it. As the return stroke is completed, the piston cup, acting as a slide valve, uncovers the compensating port and any excess fluid is returned through it to the reservoir.

A check valve in the output end of the master cylinder maintains 5 to 8 lbs. of static pressure inside the lines, which serves to keep the lips of the wheel cylinder cups tight against the cylinder walls to prevent loss of fluid and entrance of air into the system.

The dual master cylinder, first used in 1962 by Cadillac and American Motors' Rambler and now mandatory on all new cars, has two outlets, two complete piston/cup/spring and check valve assemblies, and two separate reservoirs for fluid supply.

The pistons operate in tandem in a continuous cylinder barrel, and are operated by a single pushrod linked to the brake pedal. One of the outlets is connected to the front wheel cylinders, the other to the rear ones. Failure in one system still gives braking operation to the other. Newest safety version of the dual system is a warning light that indicates failure of either side of the hydraulic system. Failure can also be felt in the pedal itself as the piston of the failing circuit will bottom before the other exerts the required pressure. Pedal travel will therefore be longer.

Replacement parts for either single or double systems, with oversize pistons and cups, are available should cylinder require honing, but the maximum that can be removed is .005-in. Should this honing depth fail to remove scores or pits, the master cylinder will have to be replaced.

When overhauling master cylinders, always use all the parts in the replacement kit to insure long rebuilt life. Use care in reassembly and cleanliness throughout to avoid any grease or dirt entering the system. Clean all parts in alcohol or special cleaning compound for hydraulic systems, and lubricate cups and pistons with hydraulic fluid when assembling.

Dual master cylinders, with their tandem piston assemblies, require a little more care when the cups and pistons are slid into the cylinder barrel, since the outlets are usually at the sides along the cylinder walls. Observe the cups as they are pushed past these holes to see that they do not turn back the edge and destroy their sealing effect. A piece of small-diameter rod, rounded and smooth on the end, can be used through the outlet hole to ease the cups past the openings. Liberal use of hydraulic fluid as a lubricant will help keep the assemblies sliding through the barrel.

Follow carefully the instructions packed with dual master cylinder kits. Some of the kits have an adjustable piston which must be set for your car. If it isn't set correctly, the brakes won't work.

To fill the hydraulic system after rebuilding wheel and master cylinders, fill

the master reservoirs and proceed as with bleeding the system, only open the bleeder valves fully and keep master reservoir filled as the foot pedal is used to pump fresh fluid into the entire system. Then bleed the system as previously described, after bleeding the master cylinder first.

Some master cylinders are equipped with bleeder valves which operate much like the wheel cylinder bleeders. To operate these, press the brake pedal slowly, and open the bleeder valve near the bottom of the stroke, then close the valve before pedal is released. Repeat, making sure that master reservoir is full, until fluid flows in a steady stream without bubbles. For bleeding without a valve, loosen fitting to brake line and force air and fluid out by pressing brake pedal. Air in system can be heard as it squirts out through fitting. Tighten and proceed with bleeding wheel cylinders. On dual masters, loosen both outlet fittings and proceed as described for single cylinders.

FLUSHING HYDRAULIC SYSTEMS

When preliminary examination of wheel or master cylinder indicates swollen or mushy piston cups, there is evidence that the fluid is contaminated by oil, kerosene, or foreign liquid that destroys the rubber cups. All wheel cylinders and the master should be rebuilt with new parts, but only after the system is flushed. About a quart of brake fluid is required. Follow the same procedure as bleeding but open bleeder valves a full 1½ turns to speed up passage of old fluid being pushed through by the flushing liquid.

After flushing, proceed with wheel and master cylinder overhaul. Upon reassembly, bleed system completely with new hydraulic fluid.

Flushing fluid, an alcohol base solvent available at parts stores, can be used for flushing the brake lines. However, many carmakers warn against its use because of the difficulty in getting it all out of the lines so it won't contaminate the brake fluid. They recommend that any flushing be done with new brake fluid only.

PARKING BRAKES

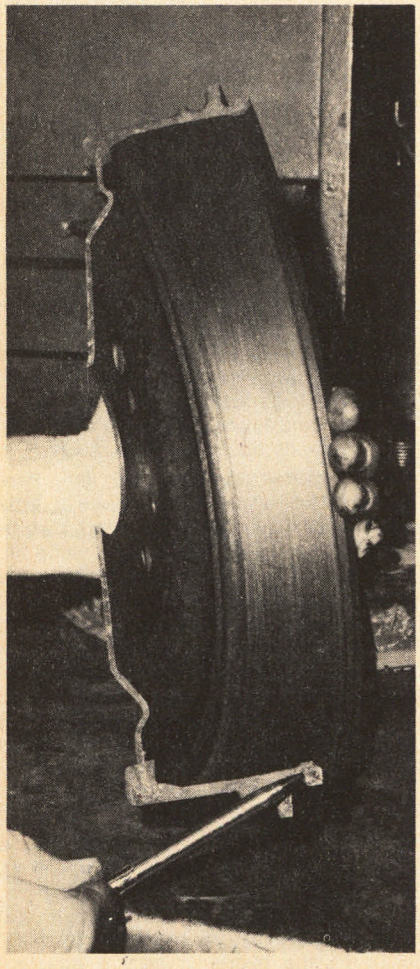
Parking brakes fall into three types: the cable-operated rear brake shoes, the cable-operated external driveshaft brake, and the cable-operated internal expanding driveshaft type. A need for parking brake cable adjustment is indicated when the parking brake pedal or lever must be activated to the limit of its stroke in order to properly hold the car when parked. A minor brake adjustment on systems without self-adjusters should be performed before adjusting cable-operated, rear-drum-type parking brakes. When this is done, check slack in rear cables to brakes. If more than 2 ins. of slack is apparent, adjust by loosening lock nut on cable usually located in the forward or single cable part of the cable system. Hold cable to prevent it from turning while adjuster is pulled up to the required 2 ins. of slack with parking brake off, then tighten adjusting lock nut. Check for drag by jacking rear wheels off the ground and turning for any indication that the parking cable is too tight.

The external driveshaft brake used on early Chrysler cars has two adjustments. Before any adjusting is done, jack rear wheels off ground and check for drag. Operate parking brake mechanism while watching external brake to determine if cable has stretched and is not closing band tightly on driveshaft drum. If there is too much slack here, tighten cable tension and check to see if band closes tightly. Should this prove ineffective, the band itself can be set closer to the drum by a band adjusting nut. Under no conditions should the clearance between band lining and drum be less than .015 to .020-in., measured by feeler guage at the band anchor point. Check by turning rear wheels by hand to detect any drag increase after adjustment has been made.

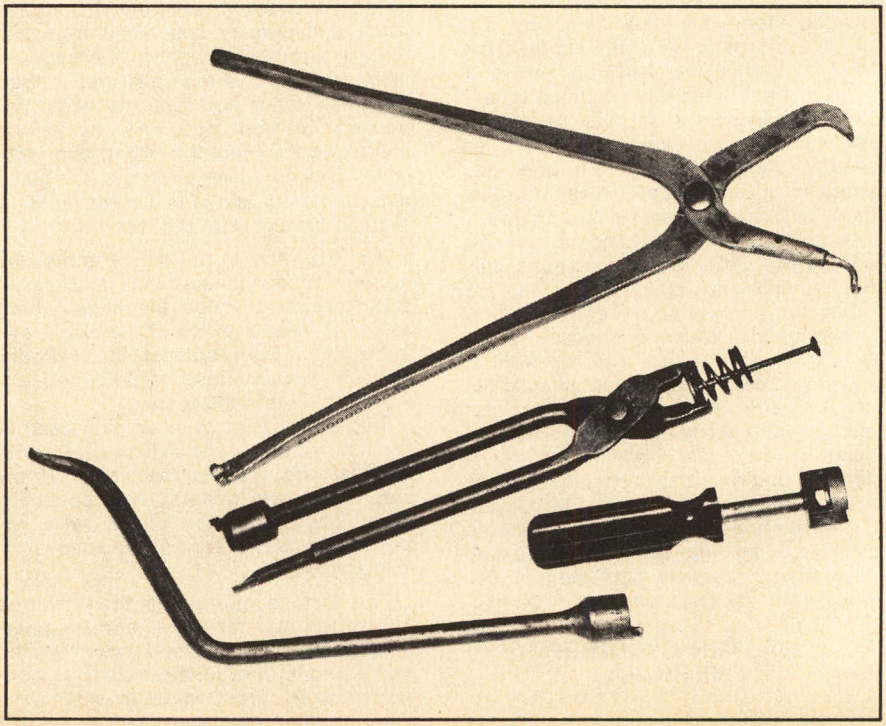
Chrysler cars were also equipped with a driveshaft brake that is just a mechanical version of the ordinary wheel brake. The first check for adjustment should be in the cable. If this does not prove effective, there is a star wheel adjuster for setting out the shoes just as on the wheel brakes. With the rear wheels jacked off the ground, set adjuster nut up until a slight drag is felt, then back off until the drag is eliminated. Do not overadjust either internal- or external-type driveshaft brakes, because sustained friction during driving can cause severe burning of all friction parts in the braking system.

POWER-ASSISTED BRAKES

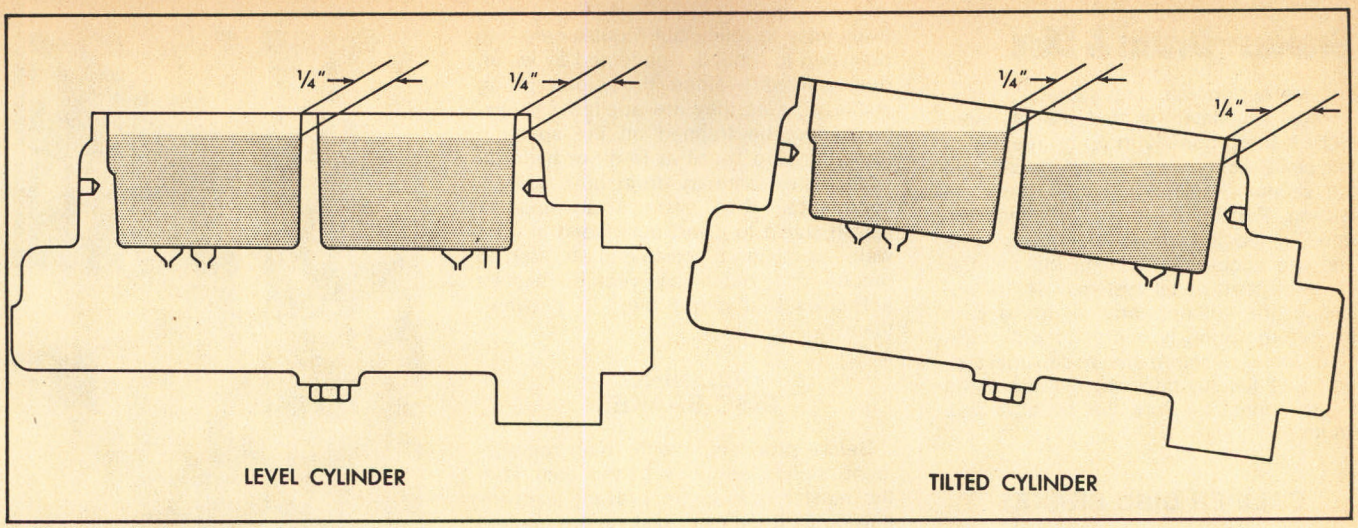
The power-assisted brake systems generally used on passenger cars do not shorten the stopping distance of the automobile. They are designed to assist in applying pedal pressure to the hydraulic system, thereby reducing the pedal force



1. Cutaway of Worn Drum



2. Brake Tools



3. Master Cylinder Reservoirs

1. This drum was so badly worn that it was necessary to completely back off the shoe adjustment in order to remove the drum from the car. Note ridge on the edge of the drum. Each make drum has maximum that it can safely be turned before it must be replaced with a new one. If turned too much, unit will overheat, warp, etc. Then you'll be in deep, deep trouble when your brakes fail at need.

2. Special brake tools make any such job a lot easier and quicker. These are a few of the tools used.

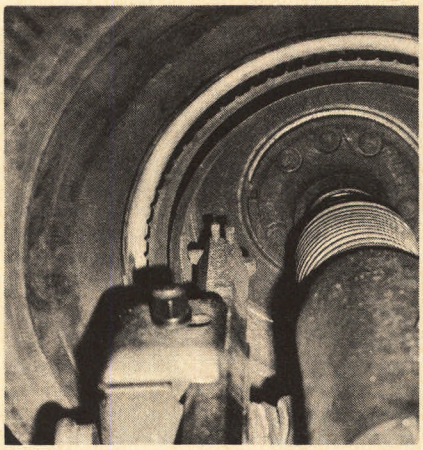
3. This illustration reveals the reservoirs in a pair of master cylinders, both filled to within ¼-in. of the top. Note the one that is tipped, or mounted at an angle, actually holds less brake fluid.

4. If the drums on a car show much wear at all they are probably grooved, therefore should be cut.

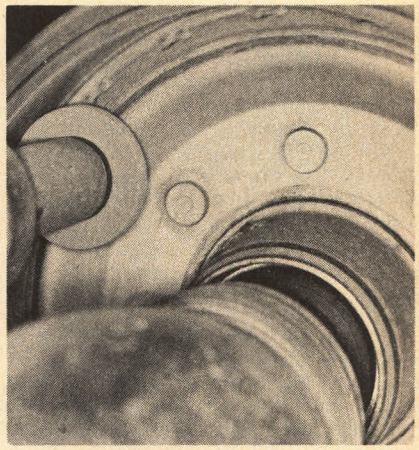
5. After being surfaced with a cutting tool, it is wise to have the surface ground with a grinding stone to remove traces of the cutting.

6. Special wrenches, such as brake bleeder wrenches, make this job easy. Angles are such that you can get to the fitting and loosen it.

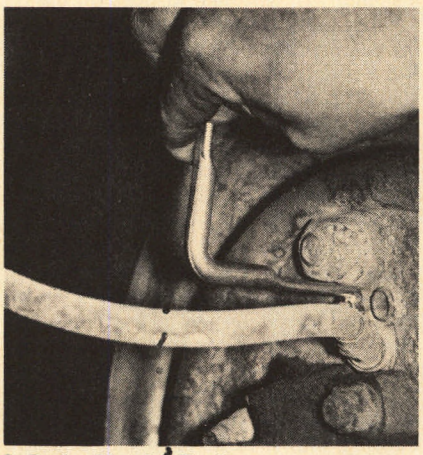
7. When doing a brake job, make it complete by inspecting lines, too. This flexible line is cracked badly, and may burst under pressure and cause a severe accident.



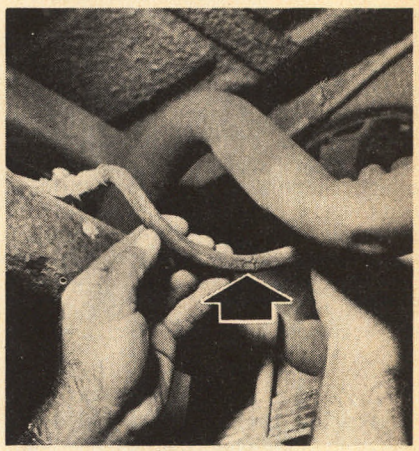
4. Cutting a Drum



5. Grinding Cutting Marks



6. Brake Bleeder Tool



7. Inspecting Brake Line

normally required in a non-assisted system. Two basic types are used on passenger cars: 1) the Bendix/Moraine composite units composed of a vacuum-actuated power unit combined with a hydraulic master cylinder, and 2) the type used by Ford and Chrysler which uses a vacuum-operated power unit that applies assisting force to the brake pedal linked to the master cylinder. Both systems use engine intake manifold vacuum to operate them, but will operate with increased pedal pressure should the system fail or braking be necessary with the engine not running.

Power units are composed of three basic elements, all of which must function to achieve assisted braking effort. These are: 1) vacuum chamber which provides the power as long as manifold vacuum is available; 2) the hydraulic master cylinder, necessary to transmit hydraulic force to the wheel cylinders; and 3) the control valve, which is operated by mechanical linkage to the brake pedal and triggers the vacuum force in proportion to the brake pedal pressure and travel distance.

Whether of the composite or isolated type, power units require much the same replacement of parts as do hydraulic systems in that every phase of their operation depends on good sealing and proper operation of the valves.

As outlined in the beginning of this chapter, follow the drive test procedure to determine if braking faults are in the hydraulic system or the power assist unit. Repairs of either the composite Bendix/Moraine or the auxiliary assist units are complicated and require a thorough knowledge of specialized repair procedures. It is best to effect repairs to power assists under the supervision of an expert, or replace the entire unit with a new or rebuilt one. However, before removing for repair, check all vacuum lines from engine manifold to the diaphragm housing, as any breaks or poor connections will hamper proper vacuum to atmospheric pressure balance and the

unit will not operate as it should.

Pedal adjustment is also critical, especially if the proper ¼ to ⅜-in. freeplay in the pedal action has been reduced and the vacuum valving is not properly releasing. Pedal adjustments are incorporated in the linkage to the power units and are accessible from inside the car on suspended pedal systems. Before adjusting any pedal clearance, make sure the return spring is operating with sufficient force to return the pedal unassisted to its full-out position. If there is no return spring, be sure the pedal is free on its pivot.

CALIPER DISC BRAKES

These have been in growing use on American passenger cars for only the past few years, but race cars and many European passenger vehicles have used them as standard equipment for some time. In general, they are used only on the front wheels of American cars in conjunction with regular drum/shoes in the rear. The Corvette employs discs on all four wheels, and solves the parking brake problem by combining the rear disc with an internal expanding, mechanically operated shoe and drum system.

The operating principle is simple. Imagine a spinning iron disc taking the place of the conventional drum. An assembly known as a caliper, mounted to the wheel spindle and containing a system of hydraulic pistons opposing each other, pushes against the preshaped lining material known as pads or pucks. With the disc in between the opposing pads, stopping is effected much like squeezing the disc between thumb and finger, but with a great deal more pressure and area. Hydraulic pressure at the wheel pistons of caliper disc brakes is almost double that of conventional drum/shoe brakes. When used with drum-type rear brakes, a proportioning valve is installed in the rear hydraulic system to prevent rear wheel lock under braking conditions by allowing more hydraulic pressure on the front, and less on the rear.

Another unit used on disc brake systems is the metering valve. It is in the line to the front brakes. It holds back the hydraulic pressure on the front brakes until the pressure builds up a little, then it trips open and allows the front brakes to come on. The delayed application of the front brakes gives the rear shoes a chance to move out against the drums. The end result is that both front and rear brakes come on at the same time.

Check valves (for maintaining residual pressure in the system) are not used on disc brakes, only on drum brakes. With a disc/drum system, there will be a check valve in the line to the rear brakes (usually in the master cylinder outlet) but no check valve in the line to the front brakes.

Self-adjusting, and with visible indication of lining wear, caliper discs are relatively easy to reline but require care and precision to rebuild. Unaffected by water, dust and dirt—since the close fitting pucks wipe as they are applied and water cannot be trapped on the spinning disc—they are sensitive to oil or hydraulic fluid the same as drum brakes. Passenger car disc systems do have a splash shield to divert dust-laden air and water as much as possible in an effort to reduce disc and lining wear caused by abrasives that might filter in between them.

RELINING DISC BRAKES

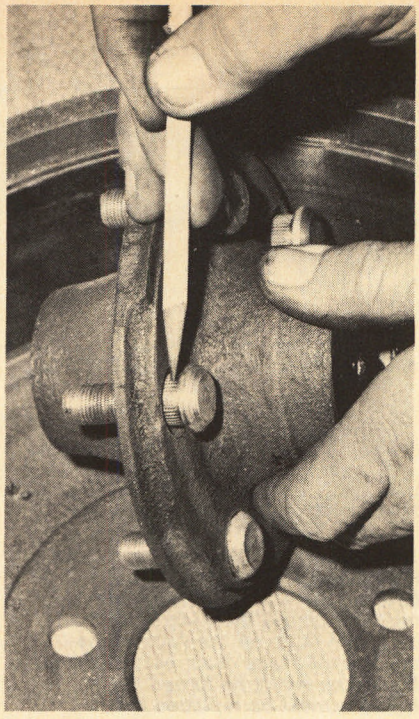
Before proceeding with lining replacement, siphon about ⅔ of the fluid from the master cylinder to prevent its overflowing as the caliper pistons are pushed back by the new thicker linings. Early GM 4-piston calipers can have their lining renewed without removing the caliper.

When inserting new linings, note the directional arrow on the steel backing of each one which indicates wheel rotation direction and provides for lining up the grain of the material in proper relation to the disc direction. The caliper pistons will have to be pushed back slightly with a thin smooth tool such as a putty knife to accommodate the new linings.

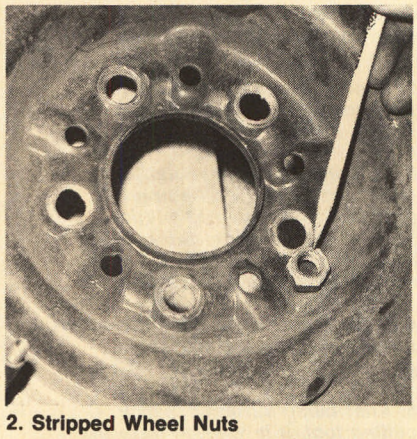
Budd caliper discs used on earlier Chrysler cars must be removed to replace the linings. This can be done without detaching the hydraulic line by removing the mounting bolts to the wheel spindle. A special tool is required that slides in between lining pads and piston insulator to hold them in position during removal. Then carefully slide the assembly off the disc, invert and remove the shoes one at a time. Replace with new linings, slide the assembly back on the disc, install the retainer and anti-rattle springs, tighten the mounting bolts and remove the special retaining clips. Apply medium pedal pressure while finishing the final tightening of caliper mounting bolts.

The Kelsey-Hayes discs, also used on earlier Chrysler Corp. and Ford Motor Co. cars, can be relined without removing the caliper assembly. They can be identified by an external hydraulic line that connects opposing piston assemblies. The lining material has a metal backing with tabs at each end and two small tell-tale detents. These detents create a scraping metal-to-metal noise against the disc, indicating that the linings need replacing. To replace, the splash shield and anti-rattle spring must be removed and the pistons pressed back into the cylinders by prying against the old lining with a thin smooth tool. It is a good idea to check the level of master cylinder fluid to guard against its overflowing during this operation.

With two pairs of pliers, grasp the tabs at each end of the lining pad and withdraw. Slide new pads into position with lining material facing the disc and the tabs seated firmly on the caliper. Replace splash shield and anti-rattle spring, then pump the pedal hard several times to advance the pistons and properly seat



1. Loose Lug Bolt



2. Stripped Wheel Nuts

3. Disc Brake Wear Sensor

linings. Check the master fluid level and bleed the system if the pedal is spongy.

CHECKING THE DISC

Most late-model cars have a single-piston floating caliper. The caliper can slide back and forth to center itself over the disc, which gives much better braking. In the old fixed caliper brakes, the slightest irregularity in the disc would knock the pistons back in their bores. When you stepped on the brake, you had to pump the pedal to get the pistons back out against the disc. With the floating caliper, it doesn't matter how wobbly the disc is. The caliper rides with the punch and gives a much better brake. All single-piston designs have to be removed from the mounting bracket in order to replace the lining.

The brake disc itself is machined to very precise dimensions and finish. Disc thickness is critical to proper lining clearance and piston travel, and the finish to proper coefficient of friction between pads and disc. Accuracy too, as to run-out or wobble, must be maintained as the calipers are solidly mounted to the spindle and must not be twisted by a warped disc. Run-out can be checked by removing the lining pads and clamping a dial indicator to the caliper. Tighten wheel bearing nut to remove all play from hub. Pick a smooth spot about 1 in. from the outer edge of disc for the indicator ball and turn it slowly. A total run out of .004-in. is maximum, and the disc must be replaced if it exceeds this because machining is not recommended.

Disc wear as to thickness also has limits and this can be checked with a micrometer. Overall wear that reduces the new thickness .035-in. for 1-in. discs, or .010-in. for 1¼-in. Corvette discs, indicates the need for disc replacement. Once a normal wear pattern has developed through use, minor scores in the disc surface have negligible effect on braking efficiency. As most discs are riveted to the hub assembly, replacement involves removing entire hub, drilling out rivets, and installing new disc. They do not have to be reriveted on GM cars as the wheel mounting studs provide necessary alignment. Be sure to secure with the wheel lug nuts when checking new disc for run-out.

CALIPER OVERHAUL

When relining caliper disc brakes, inspect inner cavity with pads removed. Any indication of moisture in the form of hydraulic fluid means that seals, pistons, or both, need replacing. To rebuild caliper piston assemblies, the entire caliper assembly must be removed.

Jack front wheels and secure with stands for safety. Remove and plug each main hydraulic line to save fluid. Remove pads, loosen caliper to spindle mounting nuts and bolts, remove and slide caliper off disc. Note location of any shims used to locate caliper.

Calipers are made in two halves, with the mating surfaces carefully machined for perfect fit. Before proceeding with any further disassembly, wash caliper thoroughly in alcohol or special brake cleaning fluid prescribed for regular drum-brake wheel-cylinder service. Dry thoroughly and separate caliper halves by removing large cross-bolts. Note that the fluid passages where they cross from one side of caliper to the other are sealed with small O-rings. Remove these carefully and keep with other parts so that they are not forgotten on reassembly. Early Kelsey-Hayes calipers do not use internal crossovers, and the external tube must be removed before separating caliper halves. Do not bend excessively or reassembly will turn out to be quite difficult.

Removal of dust boots and seals is easier if the pistons are pushed back into their caliper half as far as they will go. Carefully pry off boot with thin screwdriver, remove pistons, seals and springs, and clean them all in alcohol or special fluid. Clean out bores and all fluid passages and dry before examining them for scoring or pits. Be careful with any tools when they are used to assist removal of any parts of the piston assembly to avoid puncturing seals and boots, or scratching cylinder walls or piston.

While all rubber parts should be cleaned and examined to determine the specific cause of piston leakage, it is a good idea to replace them all from the standard rebuilding kits available. Pistons and bores should be free of scores and pits. Minor ones can be removed by honing but not more than .020-in. can be removed for cleanup. Beyond that the caliper must be replaced. Bores that show very light scratches or corrosion can be cleaned with crocus cloth, a light abrasive material similar to jeweler's rouge.

With the caliper half clamped in well padded vise jaws to avoid exterior damage, begin assembly of springs, pistons, seals, and boots. Most of the assembly can be done by hand; use hydraulic fluid liberally to lubricate all parts. GM brakes require a special tool to compress piston seal and another for installing boot seal. Use of any other tools for this purpose will result in damage to rubber parts.

Kelsey-Hayes and Budd units, if held securely in a vise, can be hand-assembled with a small smooth screwdriver used carefully to work the lip of the boot into the groove provided around the bore diameter. Use no lubricant other than

1. Check the lug bolts in the hubs and axles. Loose bolts or ones with stripped threads can cause trouble by ruining your wheel.

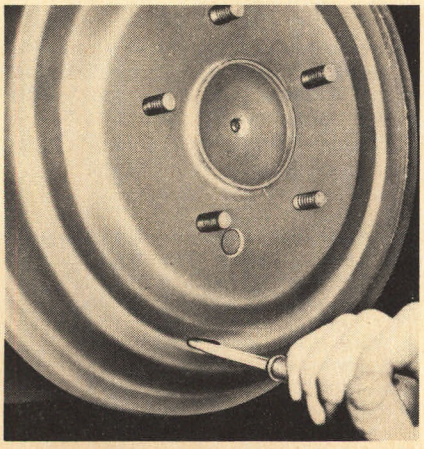
2. Here's an example of how loose lug nuts can destroy a wheel. Latter wobbled badly, grinding away at the nuts. Wheels have come off many times due to loose nuts.

3. Preventing brake wear before it costs a fortune in rotors is easy with new Oldsmobiles. This sensor makes noise when it's time to reline.

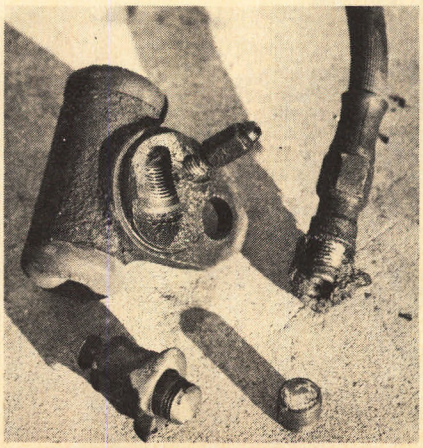
4. If your car doesn't have the self-adjusting feature, then you must make future adjustments as the brakes wear, through the drum or through the backing plate.

5. This wheel cylinder broke on a car that was not involved in an accident, and driver narrowly avoiding becoming a statistic himself. Note that anchor pin stud broke first (this pin holds brake shoe springs), later causing wheel cylinder to separate.

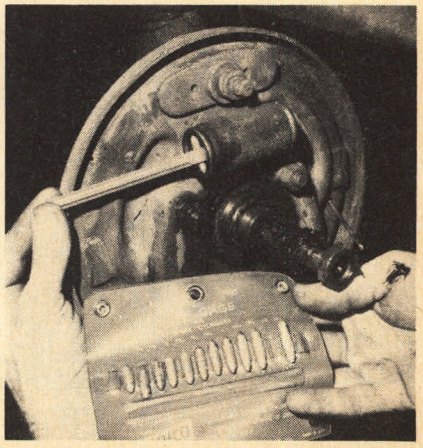
6. This Safe Gage set features gages in 1/32-in. increments. They are .005-in. oversize; if any go into a bore of the size they are designed for, this means that bore is oversize by .005-in. or more and is therefore unsafe.



4. Brake Adjustment



5. Broken Wheel Cylinder

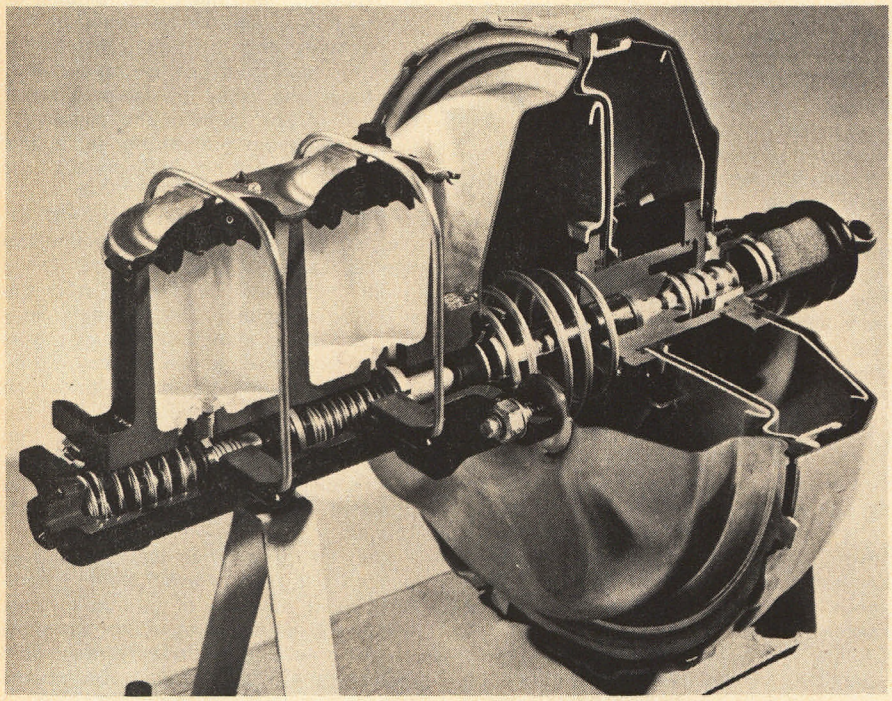


6. Safe Gage Set

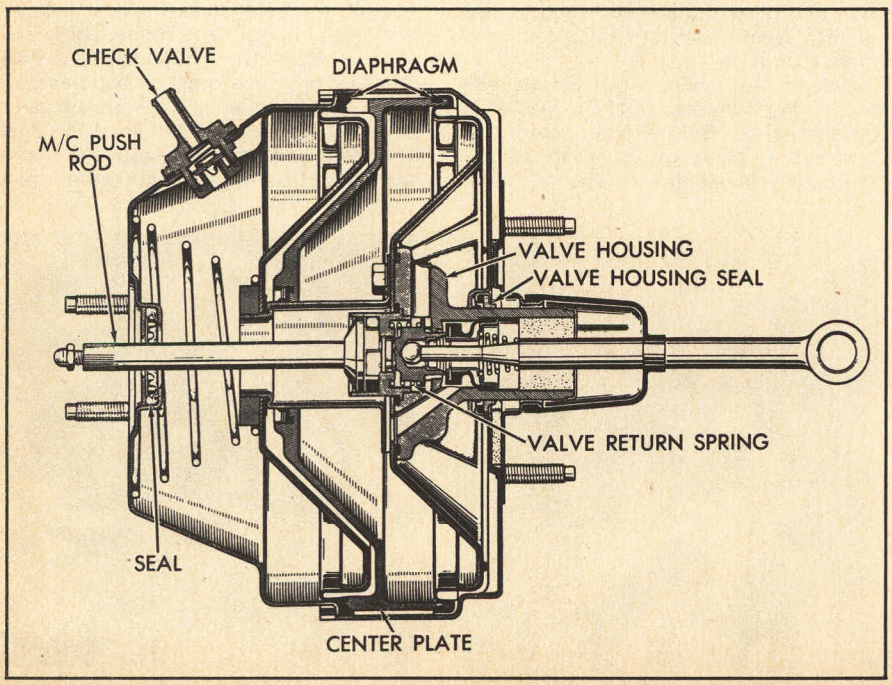
specification brake fluid as any solvent, grease or oil with a mineral base will damage the rubber parts and void all the work of the overhaul. Make sure that pistons and seals slide easily into cylinder bores, then place O-rings in cavities around fluid crossover passages and fit the caliper halves together. Make sure the mating surfaces are clean and free from nicks before installing cross-bolts and hex nuts. To insure proper pressure between caliper halves, a torque wrench is recommended for tightening assembly nuts. About 55 ft.lbs. for 7/16-in. bolts, and 155 ft.-lbs. for ½-in. will effect mating of caliper halves without damage or distortion. On caliper assemblies with external crossover, check the tube for cleanliness and freedom of fractures before carefully screwing coupling nuts to fittings.

Replace caliper assembly using a putty knife to keep pistons and boots from hanging up in edge of disc. Line up caliper to spindle mounting holes and secure with proper bolts and shims, if any. Check hydraulic line fitting for cleanliness and thread condition. Some systems use a small copper gasket in the male end of this connection which should be replaced to insure a good seal at this critical point. Install lining pads, retaining pins, anti-rattle springs, and splash shield.

Overhauling single-piston floating calipers is a lot easier than overhauling the older multiple piston jobs. To remove the caliper on AMC, Chrysler Corp., or GM cars, disconnect the brake hose, unscrew the two large guide pins, and the caliper will come right off. Ford has a similar construction, except that they use an anchor plate which comes off with the caliper. Don't forget to plug the brake hose after you disconnect it. If you don't, all your fluid will run out on the ground. Also, note the position of various clips, cotter keys, and springs on the caliper so you can get them back in the right places. Once you get the caliper off the car, the shoes will come out easily. The problem is in getting the piston out so you can install a new seal. Air pressure applied to the hole where you removed the brake line will take the piston out fast, so fast that you will probably break your hand if you are holding it in the wrong place. Auto parts stores have a tool made to grip the inside diameter of the piston and remove it, which is much safer than using air pressure. When installing the caliper, follow the instructions in the shop manual for your make and year of car. Some car makers recommend lubricating the bolts with silicone, but others say to have everything clean and use clear water as an assembly fluid. The object is to enable the caliper to slide on the guide pins so it can center itself over the disc. If you lose a mounting bolt or guide pin, get another one from your dealer. The use of ordinary bolts or pins is dangerous. It takes special hardware to withstand the tremendous forces applied to the caliper during braking.



1. Power Brake Cutaway



2. Power Unit Schematic

DISC BRAKE BLEEDING

As with conventional drum brakes, the system must be bled if the hydraulic lines are disconnected or the wheel cylinders removed. Most service manuals recommend tightening the caliper to wheel spindle mounting bolts with brakes applied in order to center them properly. Before bleeding, make sure the mounting bolts line up with the holes and then tighten snugly only for bleeding procedure. After final bleeding, apply firm pedal pressure, back off mounting bolt nuts slightly, then torque to final tightness.

Road test at low speed with several good strong brake applications to seat the pads properly before taking the car out for normal driving. Be sure you have brakes before you take the car out.

Keep one thing in mind when working on brakes: They are probably the most important single factor in good vehicle control. Brakes seldom fail, but they can if you don't inspect them periodically for wear or leakage.

1. This example of the modern power brake unit is from a 1970 Olds. In cutaway form, revealed are the internal valves and dual cylinders.

2. While the pushrod on a non-power master cylinder can angle as it contacts piston, both pushrods in most power units must remain in straight line. Nut on the end of the master cylinder pushrod is for adjustments.

METALLIC LININGS

Since the switch from mechanical to hydraulic braking systems which took place just before World War II, there have been few really significant innovations in brake design. Sure, we now have larger linings with greater surface area to handle the requirements of our bigger, faster cars; lining materials are often bonded to the shoe instead of being riveted; and brakes are even self-adjusting these days—but these are *refinements* in hydraulic braking systems.

Probably the most original attempts at innovation have come in brake lining materials, beginning with the sintered iron variety offered as an option on '65 Chevys. Unfortunately, these turned out to be pretty hard on the brake drums, souring many owners on the concept that there was any better lining material than the asbestos composition used in the past. But a few years ago, a new powdered metallic lining was made available and this time, it looks as if metallic brakes are here to stay. The performance people accepted it immediately and as word spread, after-market brake sales of Velvetouch Metalik began to rise steadily. The secret of Velvetouch Metalik is simple enough—it's a soft metal composed of graphite-like particles which come loose when its surface is scratched.

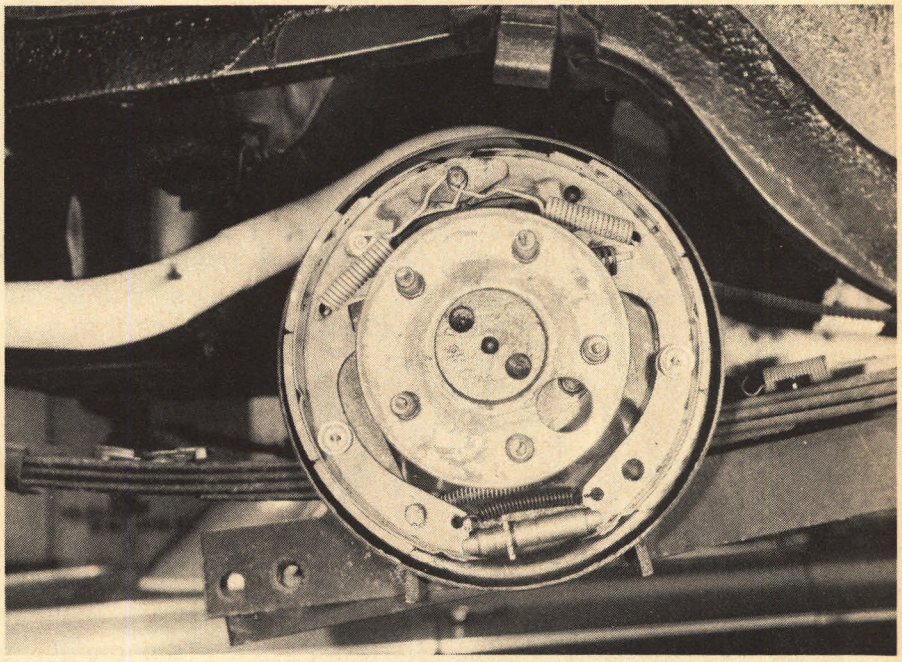
Heat generated by hard braking at high speeds causes the asbestos composition of ordinary linings to crystalize and then glaze. This acts as a lubricant and lowers the coefficient of friction between drum and lining to almost zero. But when Velvetouch Metalik is used under identical circumstances, the molecules of the lining expand, actually increasing the frictional grip between drum and lining. But of equal importance, the frictional grip does not lessen under repeated high speed stops. The lining dissipates heat, and that ends the serious problem of brake fade for those cars so equipped.

Such brake linings have other important advantages, particularly for those drivers who tend to treat their brakes hard. Lining life is approximately double that of ordinary linings; splashing through water puddles, snow and slush does not affect braking efficiency; and fewer adjustments are required than with many standard linings.

Installing Velvetouch Metallik linings is done just as with regular linings, but on cars equipped with self-adjusting brakes, the self-adjustment mechanism has to be removed as the linings must be completely clear of the drum after initial adjustment. Leaving the self-adjuster in operation causes a constant drag factor that will wear down the powdered metal linings quite rapidly.

Driving a car immediately after Velvetouch linings have been installed should be done with extreme caution, as the brakes will only slow the car down the first few times they are applied—you cannot stop the vehicle completely. The proper technique for seating the linings properly is to brake a number of times at a speed of between 20 and 30 mph to heat them up, then park the car and let the linings cool completely. At this point, efficiency rises to about 75%, reaching 100% as seating is completed through repeated use, a process that takes about two weeks for the average driver.

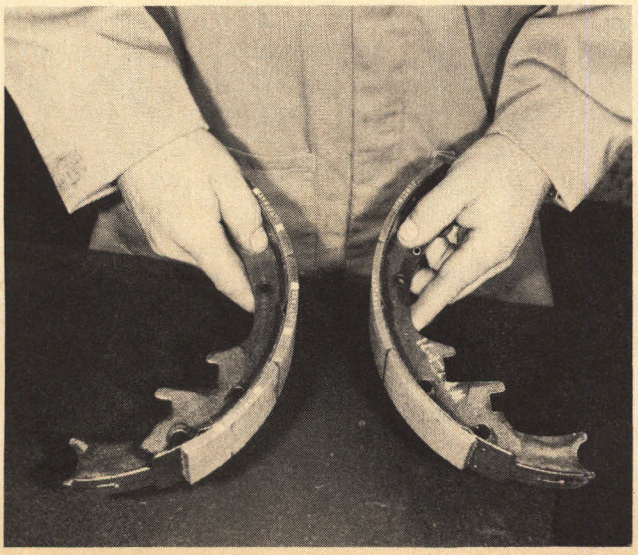
If you're going to drive fast, you should be able to brake with confidence that the car is going to *stop*. And if you find it necessary to brake hard several times, it's nice to be able to place your trust in those small discs or linings that do the job for you—with metallic brakes, the odds in your favor rise considerably over the organic linings you're probably driving on now.

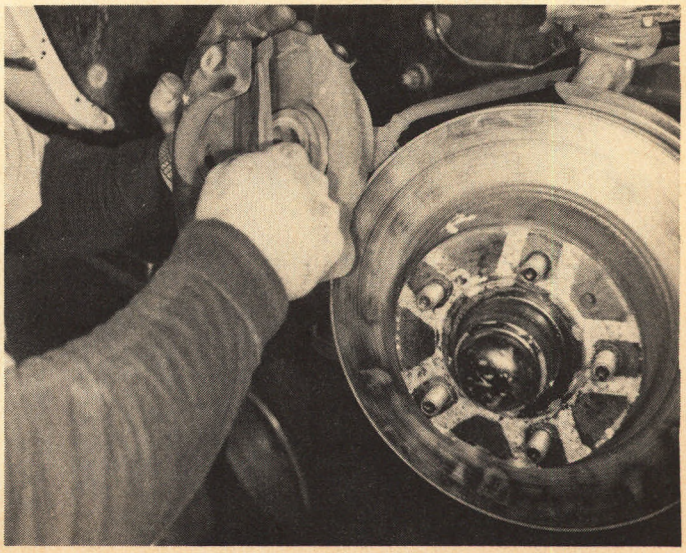


3. Velvetouch Metalik linings are installed in the same manner as ordinary shoes, except that the self-adjuster is not used and the bottom hold-down spring locks the star wheel in place.

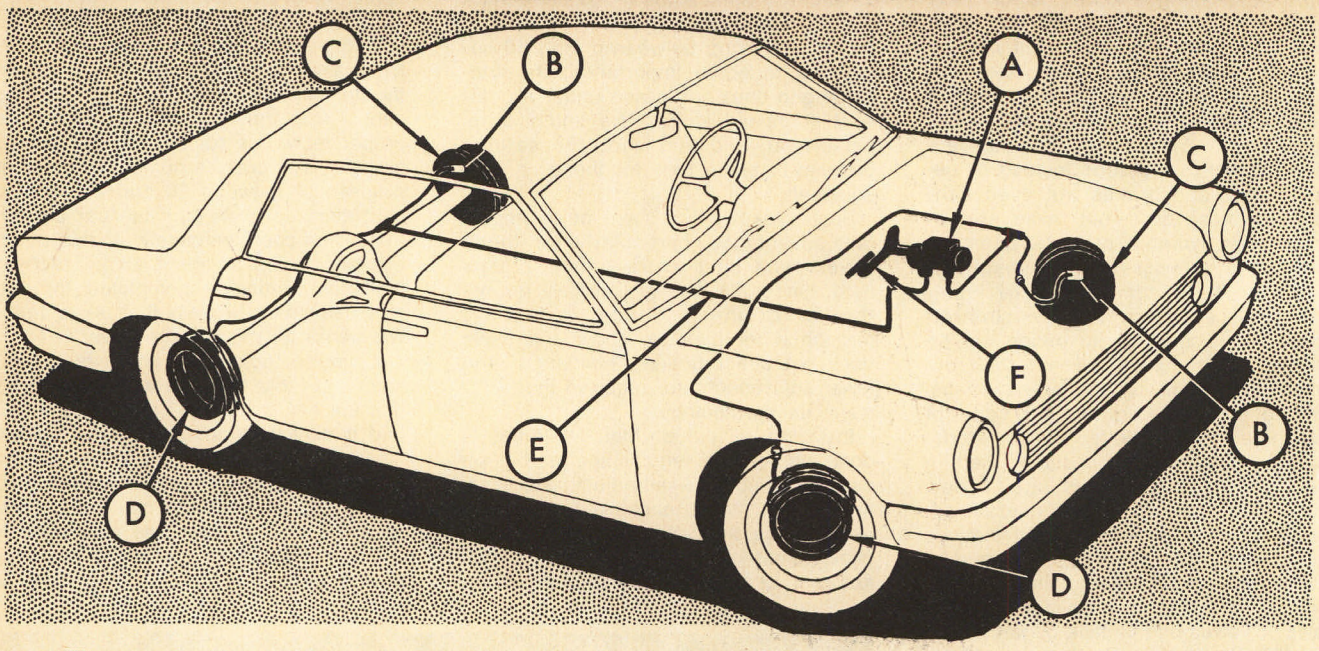
4. For a duo servo system such as the Mustang, primary shoes are stamped Pri or For; secondary shoes are stamped Sec or Rev, but you can tell them apart easily—the forward shoe (right) is thinner.

5. Metalik disc pads are replaced in the caliper just as standard ones would be. Once the caliper is secured in place, you're ready to put the wheels on and seat the new pads.

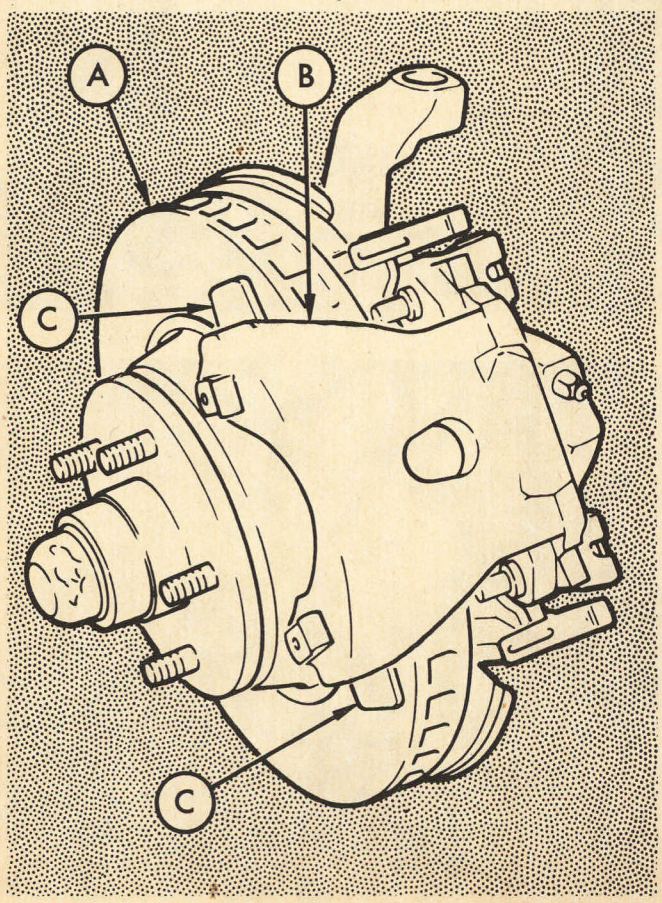




TROUBLESHOOTING HYDRAULIC BRAKES

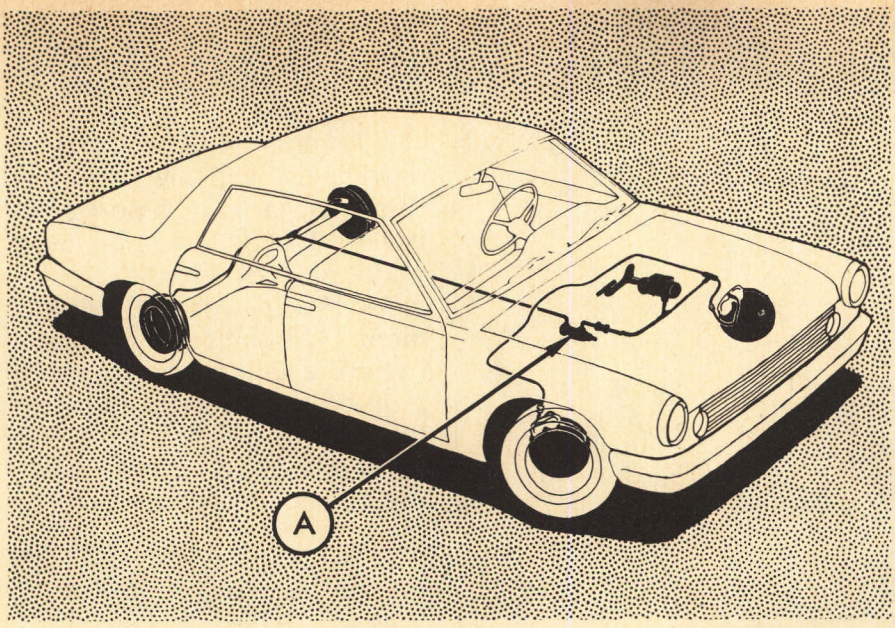


There are three basic types of hydraulic brakes on automobiles: drum or "conventional" brakes, disc brakes and brakes (either drum or disc) that are assisted by a power booster (power brakes). The brake system parts are shown in this drawing. The master cylinder (A) contains the reservoir of fluid used in the system, and the brake pedal (F) is connected to the master cylinder by a mechanical linkage. When you depress the brake pedal, hydraulic fluid under high pressure is forced out of the master cylinder into the brake lines (E) and directly to the four slave cylinders (B) inside the brake housings. These slave cylinders (normally referred to as wheel cylinders), acting under the pressure of the fluid, move the brake linings (D) so that they come in contact with the inside of the four brake drums (C). The friction between the brake linings and the drums is the force that slows the car down.

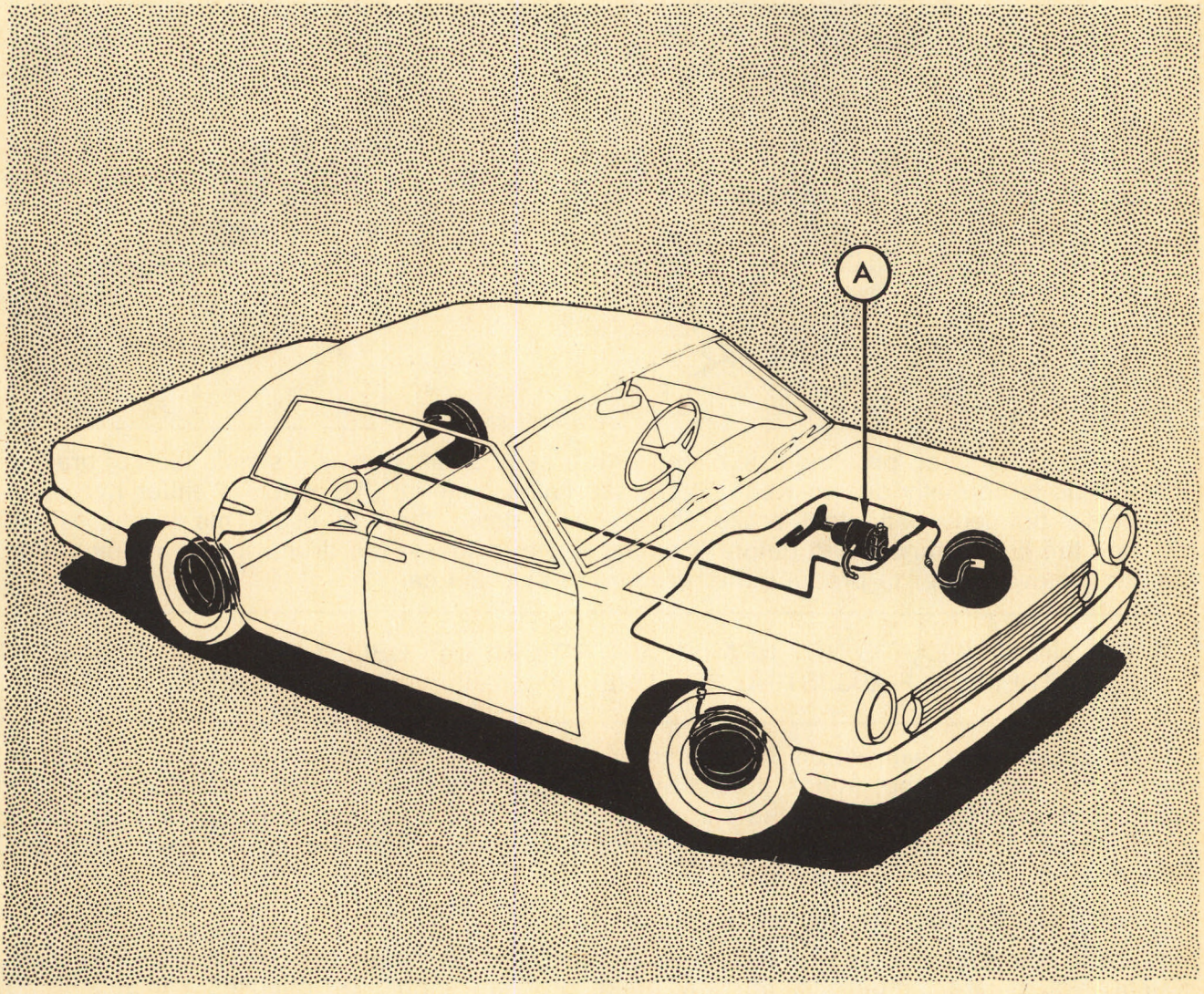


The disc brake system works on the same general principle, but instead of having the brake linings inside a drum as in the conventional brake system, the disc brake system uses a steel disc (A) which replaces the drum. This disc or "brake rotor" is attached to the hub where the wheel bolts on. Small patches of brake lining in pads are held inside a cast metal part called a caliper (B). This caliper performs the same function as the wheel cylinder: It supports the brake linings. When pressure is applied to the brake pedal, fluid forces the pads (C) against the brake rotor, providing the same friction process as with conventional brake systems to slow the car down. The caliper is held in a mounting which prevents the caliper from rotating but allows it to move from side to side slightly to self-align with the brake rotor.

Disc brakes are generally found only on the front wheels of a car, though many sports cars have disc brakes on all four wheels. The discs are more efficient than drum brakes and are becoming more common. Since the usual pattern is to have disc brakes on the front wheels only, some form of adjustment is necessary to balance the braking action between front and rear wheels.

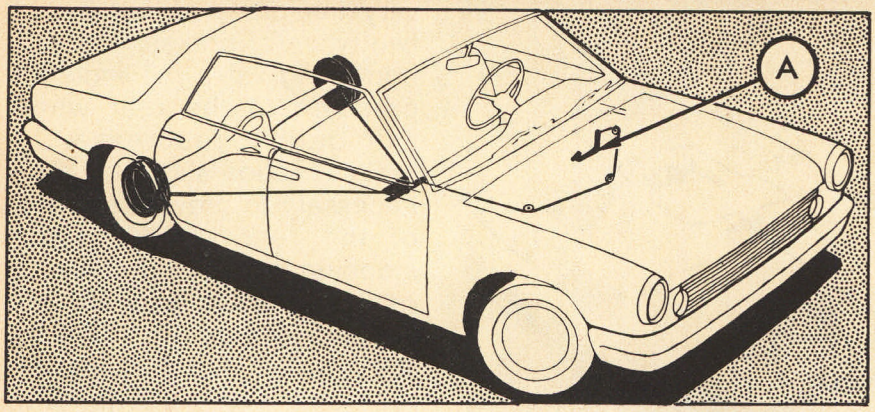


This adjustment is done by installing a proportioning (metering) valve in the line to vary the pressure felt by the two types of brakes. The proportioning valve (A) limits the pressure to the rear wheel cylinders to decrease the braking action slightly. This is necessary to prevent skidding of the rear wheels. When stopping quickly, the weight of the car is transferred (thrown forward) to the front suspension. This makes the rear of the car lighter than the front. Equal braking action would cause the rear wheels to lock up and skid.

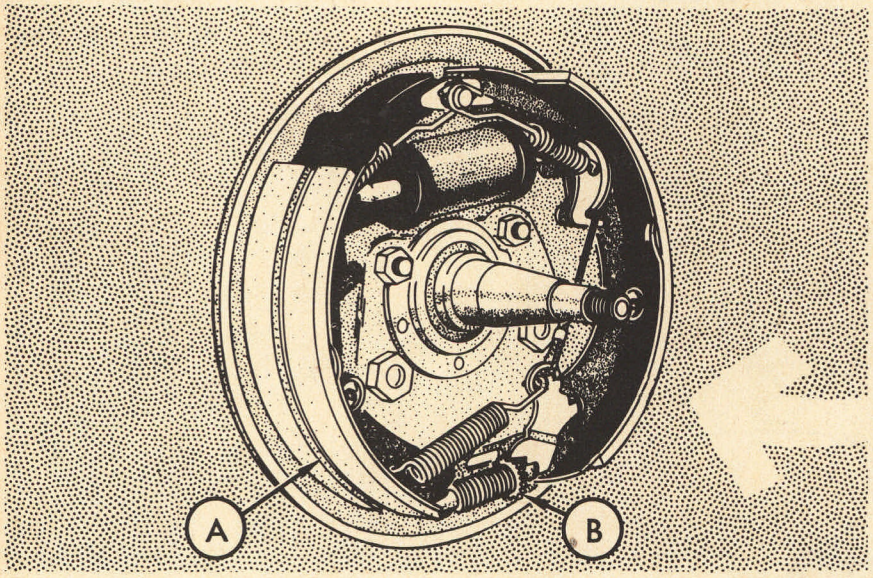


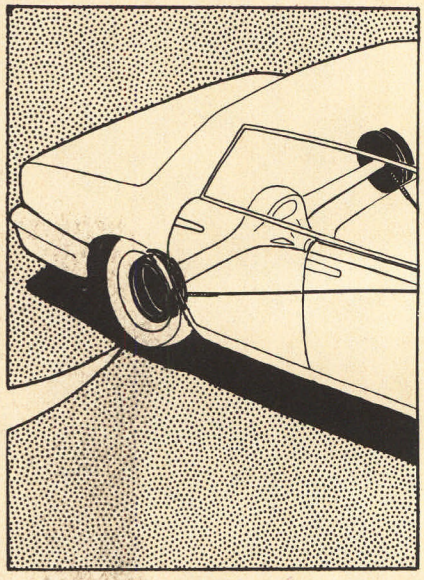
Power brakes may be drum, disc or the highly popular combination of the two. Power brakes utilize engine vacuum to apply added pressure to the master cylinder linkage just as if you were pressing harder on the pedal. When the pedal is depressed, the vacuum booster (A) aids and multiplies the force of your leg to apply hydraulic pressure to the braking system. This is a definite aid in stopping large, heavy, late-model automobiles. Failure of the power portion of the power brake system does not destroy braking entirely, but it can mean uncomfortably hard pedal pressures are required to stop the car.

TROUBLESHOOTING HYDRAULIC BRAKES



Another linkage which is associated with the brakes is the mechanical emergency brake. This is actuated by a hand or foot handle (A) inside the driver's compartment. The emergency brake (when applied) causes the rear brakes to lock and hold the car in position (until released by the driver) when the car is parked.





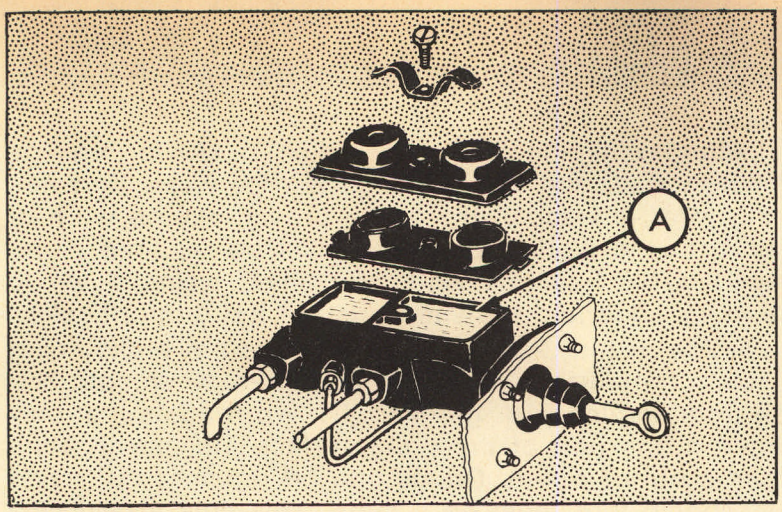
The most common problem associated with brakes of all types is a simple lack of braking ability. This is normally due to wear. The brake lining material (A), which is either riveted or chemically bonded to a steel brake shoe, wears down through use. This increases the distance the lining must travel before it contacts the inside of the drum. It also requires that the pedal move farther to produce the pressure to stop the car.

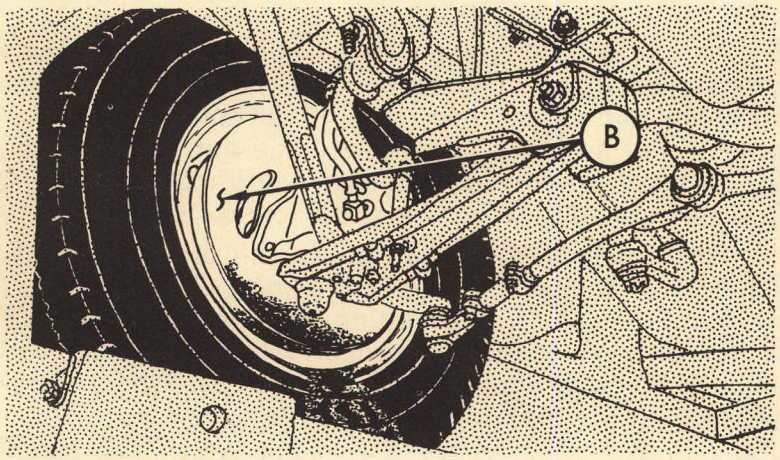
NOTE: LINING WEAR IS NOT NEARLY AS CRITICAL A PROBLEM WITH DISC BRAKES, DUE TO THEIR SELF-ADJUSTING FEATURE.

All automobiles with drum brakes are equipped with an adjusting mechanism (B) to reduce the distance the linings must travel to reach the drums. Most are adjusted with a special tool from the outside of the car, but some cars are fitted with a special linkage inside the drum which performs the adjustment automatically each time the car is driven backward for a short distance.

TROUBLESHOOTING DRUM BRAKES

There are many brake troubles that can occur other than total failure of the brake system. Not all are dangerous, but any brake problem should be checked immediately to make sure there is not some serious trouble developing. We will take the common problems one at a time and give troubleshooting procedures for each situation. Remember: *check the obvious first!* A careful visual inspection of the brake components is the first step to troubleshooting the system when a problem is suspected. You need not remove the wheels and drums to get a good idea of the condition of the brakes. Unless the brakes are worn beyond the adjustment point, the problem is usually associated with some form of brake fluid leak from the system. This can usually be seen without removing any parts.

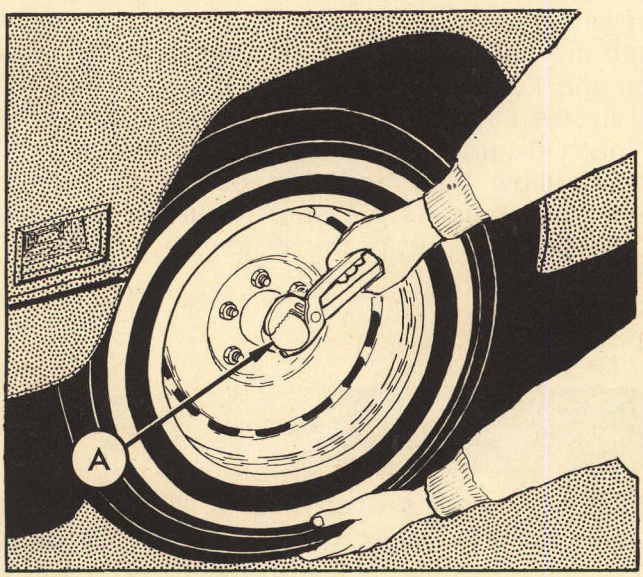


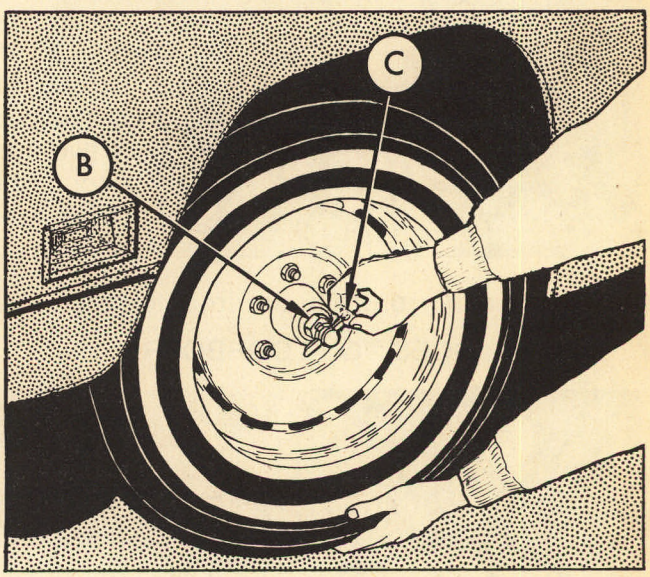


Inspect the fluid level in the master cylinder (A) first. If it is low, fill it with the correct type of fluid recommended in the shop manual for your car. Carefully examine all of the lines leading from the master cylinder to each wheel. Look for signs of leakage. These are usually apparent as stains or greasy-appearing areas on brake lines or on the body or frame directly under lines. Examine the wheel backing plates (B) and the insides of the tires on each wheel for fluid stains. Such stains indicate that there is a leak in one of the wheel cylinders.

You can confirm the leak by removing the wheel and drum to inspect the cylinder. At the same time you may also inspect the brake linings to see if they are worn to the point where they require changing (approximately ⅛-inch remaining on the brake shoe). It is better to inspect the front wheel linings first, as they wear more quickly than the rear. Jack up the front end of the car and place an axle stand under the frame or front suspension before removing the wheel.

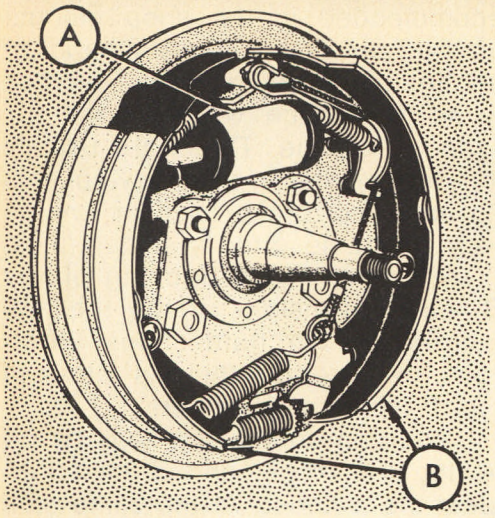
WARNING: DO NOT INSPECT OR SERVICE ANY PORTION OF THE UNDERSIDE OF THE CAR WITHOUT INSTALLING A SAFETY LIFT SUCH AS A JACKSTAND. DO NOT RELY ON A BUMPER JACK TO SUPPORT THE AUTOMOBILE SAFELY. SERIOUS INJURY CAN RESULT.

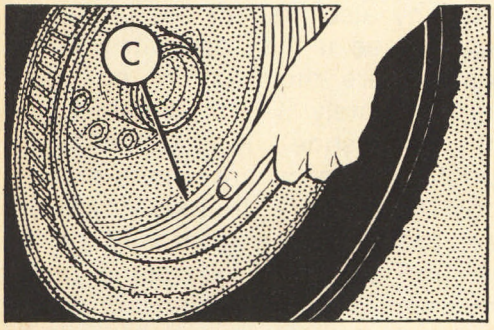


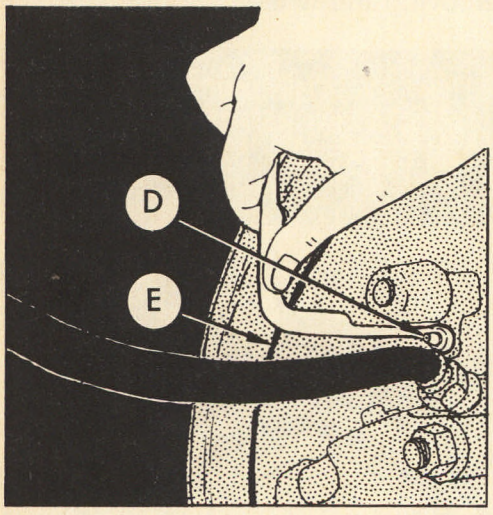


Remove the hubcap to gain access to the dust cover (A) over the wheel retaining nut (B). This nut is held by a cotter key (C) to prevent the nut from loosening. The cotter key can be removed with pliers. Remove the nut and slide the wheel and drum off the spindle. The wheel bearings will often come off the hub along with the wheel. The bearings should then be wrapped in a clean cloth to prevent them from getting dirty.

TROUBLESHOOTING HYDRAULIC BRAKES







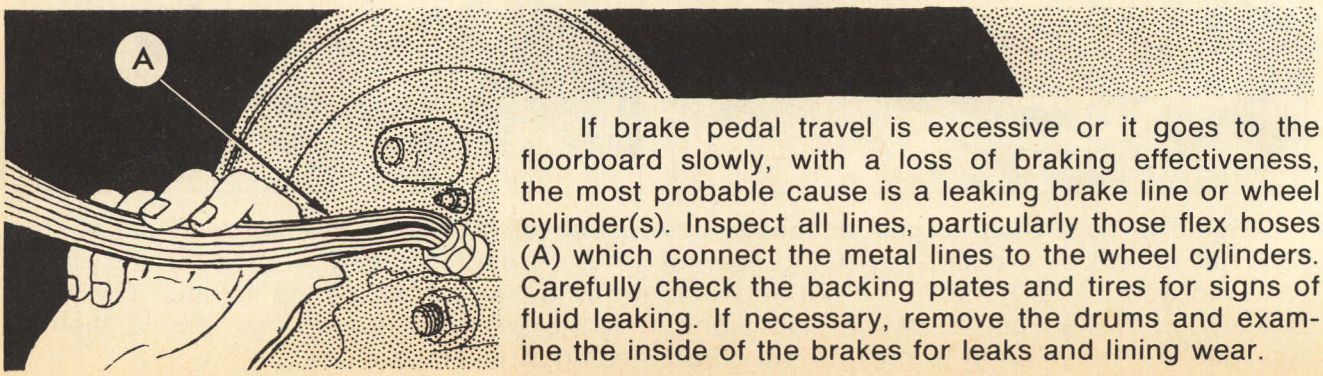
After examining the wheel cylinders (A) for leakage of fluid, check the brake linings (B) for wear. If severe lining wear is evident, the brake drums may be worn or scored to the point where they must be repaired or replaced. (This happens when the lining wears down to the metal shoe and the shoe rubs on the drum.) Look at the inside of the drum. The area where the brake lining contacts the surface of the drum should be smooth and free from scratches or grooves (C). Worn areas that only show on one part of the drum surface indicate that the drum is out of round. Drums can be repaired by having a mechanic turn them on a lathe. This cuts a new face on the inside of the drum that is perfectly round and true. New brake linings can then be installed. Whenever brake replacement or repair is done, the wheel cylinders should be rebuilt with new parts. This is not a hard job and can be undertaken by the average auto owner without too much trouble. Consult the shop manual for information on doing your own brake jobs.

If the wheel cylinders or any of the brake lines are loosened for inspection or maintenance, the brake system must be "bled." Bleeding the brake system is accomplished by opening a small valve (D) located on the back of each wheel backing plate (E). When open, this valve allows brake fluid to escape to remove any air bubbles that may have gotten into the system. To bleed brakes you need a supply of brake fluid to refill the master cylinder as fast as fluid is lost at the wheel cylinder. This will prevent more air from entering the system (by allowing the reservoir to empty) while you are bleeding it.

Most professional mechanics use a pressure bleeder, which provides air-free fluid to the top filler cap of the master cylinder. You can get by without the pressure bleeder if you are careful not to let the reservoir run dry. Do not allow the fluid to run for more than a couple of brake pedal cycles before shutting the valve. Bleeding is a two-man job. One man opens and closes the valve at each wheel to allow fluid and trapped air to escape while the other man applies pressure to the brake pedal to force the fluid and air out of the system.

Some major drum brake troubles are:

PEDAL GOES TO FLOORBOARD



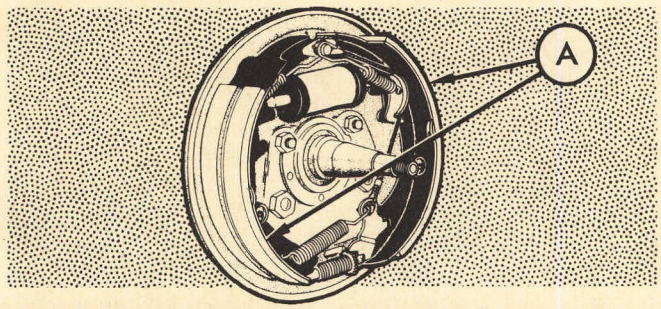
If brake pedal travel is excessive or it goes to the floorboard slowly, with a loss of braking effectiveness, the most probable cause is a leaking brake line or wheel cylinder(s). Inspect all lines, particularly those flex hoses (A) which connect the metal lines to the wheel cylinders. Carefully check the backing plates and tires for signs of fluid leaking. If necessary, remove the drums and examine the inside of the brakes for leaks and lining wear.

Check the level of the fluid in the master cylinder. If the fluid level is near normal and there is no sign of leakage in the lines or wheel cylinders, the master cylinder may be at fault. The seals inside the master cylinder may be worn, allowing fluid to seep back past the plunger. Air in the system (causing a spongy pedal) may also be the problem. Bleed the brakes to see if that will restore brake pedal firmness. Adjust the brakes.

BRAKE PEDAL FEELS SOFT

A soft or spongy pedal feeling is most often caused by air in the system. Check for signs of leakage, bleed the system and adjust brakes. Another cause may be worn brake linings.

BRAKE PEDAL FEELS HARD

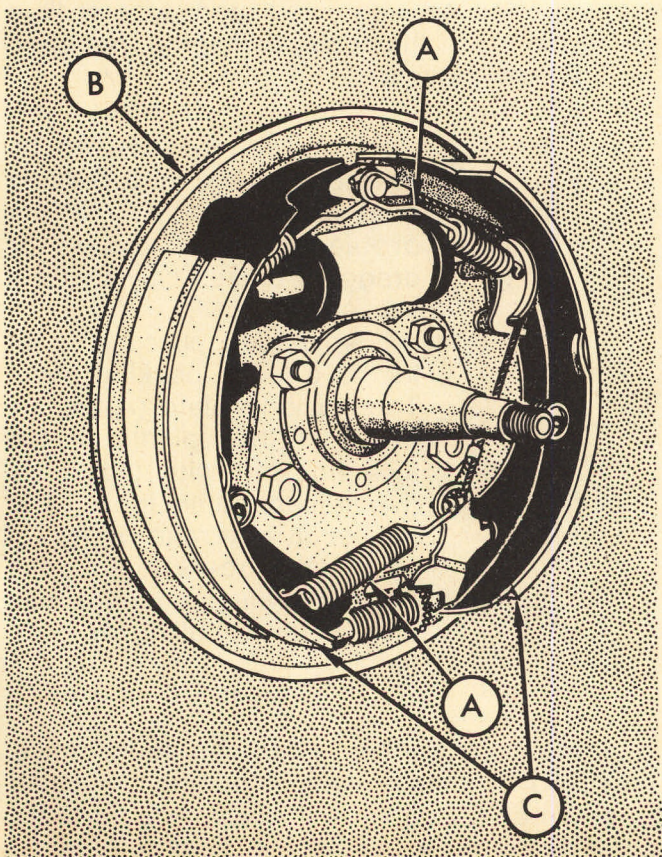


If it requires hard pedal pressure to stop the car (non-power brakes), the problem is usually burned or glazed brake linings (A). This is caused by excessive heat buildup during braking. Once the surface of the brake lining has become glazed, it will not work well until the brake linings are shaved (roughed up) to uncover unglazed brake lining material.

CAUTION: SHAVING LININGS CAN BE ACCOMPLISHED EASILY AT HOME BY REMOVING THE WHEEL AND DRUM AND SANDING DOWN THE LINING WITH A ROUGH PIECE OF SANDPAPER. BE SURE TO SAND LIGHTLY AND COMPLETELY AROUND THE ARC OF THE BRAKE LINING. FAILURE TO DO SO WILL CAUSE FLAT SPOTS ON THE LINING AND UNEVEN BRAKING POWER.

Check the shop manual for information or take the linings and drums to a mechanic for work. If your type of driving places a great demand on the brakes, your mechanic may suggest a switch to a different type of lining that resists glazing.

ONE BRAKE DRAGS

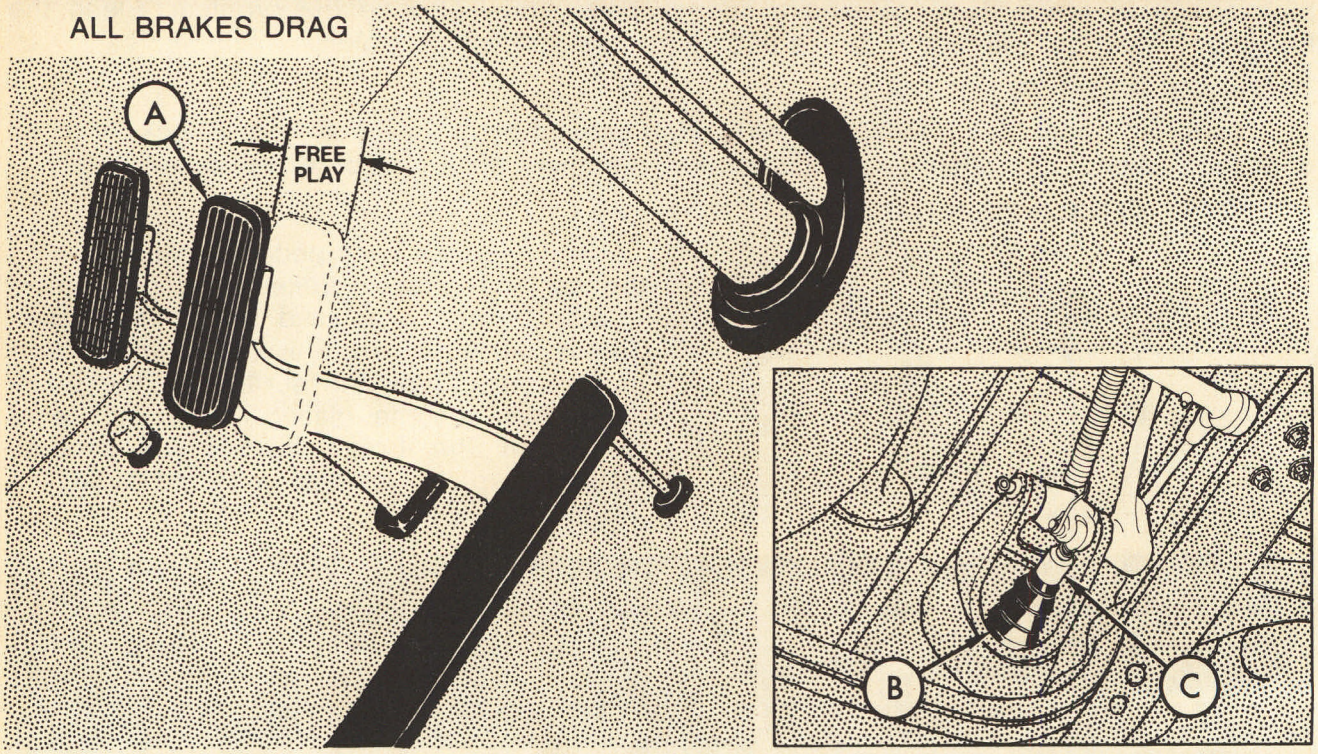


A single brake which does not release all the way or "drags" will cause extreme wear of the lining. This is usually first noticeable as a hesitation on brake release or a sound heard when the car first starts to move. A dragging brake builds up a lot of heat. The driver may discover it by the smell of burned lining or signs of wheel bearing grease leaking down on the tire. Wheel bearing grease becomes quite hot when a brake is dragging and can run out from under the dust cover. Dragging is usually due to a weak or broken brake return spring (A). It can also be caused by a clogged brake line or a wheel cylinder which is dirty and will not return to the relaxed or off position.

Another problem, an uncommon one, is a brake shoe (C) that hangs up on the edge of the backing plate (B). Though rare, it can happen. A very badly warped or egg-shaped drum can cause the brake to drag, with the lining coming in contact with the drum each time the wheel revolves, even though the lining is retracted to its normal off position.

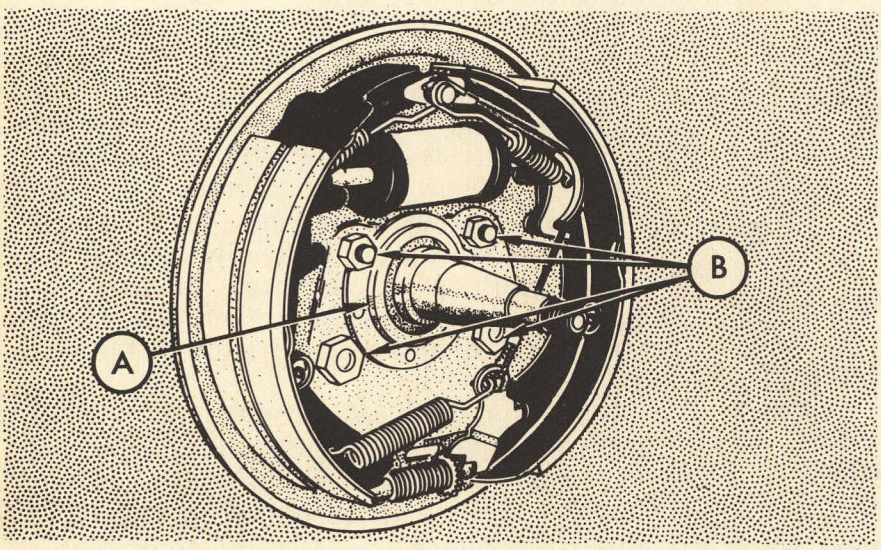
TROUBLESHOOTING HYDRAULIC BRAKES

ALL BRAKES DRAG



If all brakes drag, the problem is usually a misadjustment in the linkage between the master cylinder (B) and pedal (A). If the linkage (C) is adjusted so that there is no free play when the pedal is not depressed, it can cause the master cylinder to apply a small amount of pressure to the system at all times. If the master cylinder is contaminated with dirt or other foreign material, it can jam the piston in the cylinder so that partial pressure is applied to the system at all times. Finally, if the brake fluid has been replaced with some other type of fluid (such as lubricating oil), it can cause a chemical reaction with the seals, damaging them and causing binding of moving parts inside the master and wheel cylinders.

BRAKES GRAB OR CAR PULLS TO ONE SIDE



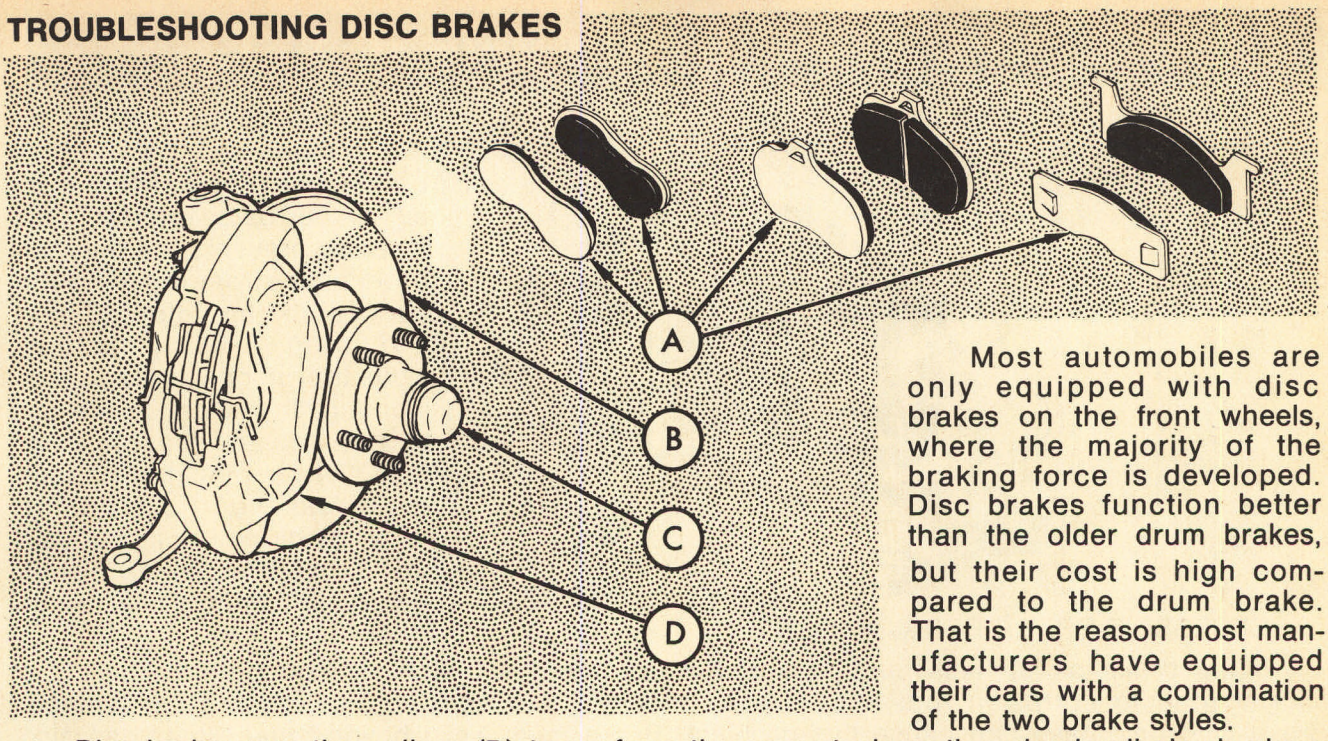
This can be caused by grease or brake fluid seeping onto the linings. Any of the problems listed above for dragging brakes can create a similar effect.

An added possible problem is a loose backing plate. The backing plate (A) is fastened to the spindle or the axle housing with four bolts (B). It can come loose, and the result is erratic or "grabby" brake operation. Loose or worn wheel bearings can also result in pulling or grabbing.

NOISY BRAKES

Almost any portion of the interior of the brake drum and backing plate can cause noise. Look for loose springs, brackets, nuts, etc. Squealing of brakes when stopping is usually caused by a buildup of brake dust inside the brake area. This dust is finely powdered brake lining which collects in the bottom of the backing plate lip and the inside of the drum. Grease on the brake linings will also cause a squeal, as will brake fluid, but this will normally be accompanied by grabbing of the affected wheel.

TROUBLESHOOTING DISC BRAKES



Most automobiles are only equipped with disc brakes on the front wheels, where the majority of the braking force is developed. Disc brakes function better than the older drum brakes, but their cost is high compared to the drum brake. That is the reason most manufacturers have equipped their cars with a combination of the two brake styles.

Disc brakes use the caliper (D) to perform the same task as the wheel cylinder in drum brakes, but the caliper also acts as a holder for the brake lining (A), which is in the form of pads rather than curved shoes. The reader is advised that the caliper should not be taken apart. This is a job for a trained mechanic equipped with special tools and knowledge of disc brakes.

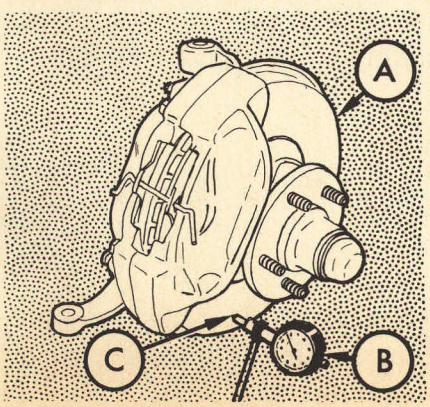
The rotor (B) is a steel disc attached to the wheel hub (C). It is machined perfectly flat on both sides. The caliper (D) rides over it in such a manner that when the brakes are applied, the pads grip the disc between themselves, creating tremendous pressure. The basic troubleshooting steps for disc brakes are the same as for the drum brakes. Careful examination of the master cylinder, lines and the calipers for leakage of fluid is the place to start. Some calipers are designed so that the amount of brake lining left on the pads can be visually checked and measured without disassembling the calipers. See the shop manual for information. The following is a list of the troubles which apply specifically to disc brakes:

EXCESSIVE PEDAL TRAVEL

This can be due to an air leak or fluid leak somewhere in the system, or fluid level can be low in the master cylinder. If the brake pads are not correctly positioned or seated in the calipers, they can cause this trouble. If the rear drum brakes are considerably out of adjustment, they can cause the problem. Wheel bearings that are set too loose can also produce this symptom.

BRAKE OR PEDAL CHATTER

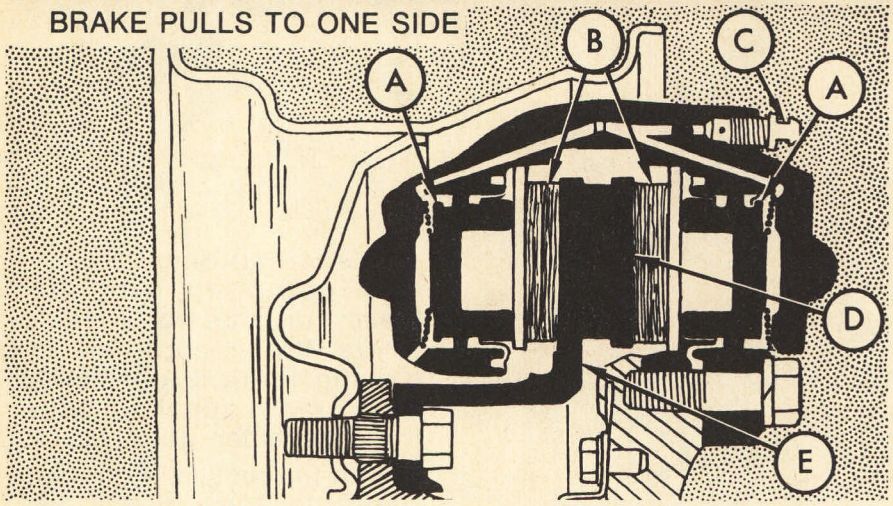
Chatter, or a pulsating vibration felt when the brakes are engaged, is usually caused by a bad rotor (A). The rotor can become warped, bent or worn so that it no longer has flat surfaces for the brake pads to grip. Another problem could be that the front wheel bearings are worn excessively, allowing the rotor to wobble. (The rotor is attached to the hub which is supported by the wheel bearing on the spindle. If the hub wobbles, the sides of the rotor will not be flat to the surface of the brake pads at all times.)



A rotor that you suspect is not true can be checked with a special tool known as a dial indicator (B). This indicator has a sensitive gauge movement which measures movements of the measuring tip (C) in thousandths of an inch. This indicator is set up on a stand so that the tip of the gauge is against the surface to be measured—in this case, the braking surface of the rotor (A). When the rotor is turned, the gauge will show any variations in the surface. This is known as measuring lateral runout. Another measurement can be taken on the rotor, namely measuring the thickness of the rotor to see if it has high and low spots in its thickness, which will produce the same symptoms as a warped rotor. If you do not have access to a dial indicator, have the rotors checked by your local mechanic.

TROUBLESHOOTING HYDRAULIC BRAKES

BRAKE PULLS TO ONE SIDE



This can be caused by the pistons (A) behind the brake pads (B) becoming frozen by corrosion or dirt. This freezing prevents the pads on one caliper from touching the surface of the rotor (E) and providing braking action. Note that if one brake is not working, it will cause the car to pull toward the *opposite* side. Other possible causes are grease or fluid on the disc linings or rotor or a caliper that is loose or not in good alignment (D) with the rotor.

EXCESSIVE BRAKE PEDAL EFFORT

If the brake pedal feels hard, it could mean that the pistons (A) on both calipers are sticking due to corrosion, but it is unlikely that this will happen on both brakes at once. Brake fluid or grease can cause this problem. Brake pads worn beyond their limits can also be a cause. On Ford cars, the proportioning valve which adjusts braking pressure between front disc brakes and rear drum brakes could be malfunctioning. Since most disc brake systems require some form of power assist to get the high fluid pressures required to make disc brakes work effectively, high pedal pressures coupled with a reduction in braking ability could mean that the power portion of the braking system is bad. (See the section of this chapter on power brakes.)

BRAKE GROAN

Squeaking or groaning disc brakes can be irritating, but the noise is not an indication of a brake problem. It is caused under certain pedal pressure conditions by the rotor slipping between the brake pads. There are commercial liquids on the market that are supposed to reduce the noise, but their effectiveness in questionable.

BRAKE RATTLE

This is a problem that can be corrected. The most likely source of the difficulty is a missing anti-rattle clip on one caliper. This clip holds the pads under a slight spring tension to prevent noise when they are not in contact with the rotor. Another possibility is that brake pads have been installed that are undersized for the holes in the caliper.

NO BRAKING EFFECT WHEN PEDAL IS DEPRESSED

This has much the same cause as with drum brakes. Complete loss of braking effect is usually a sign of a ruptured line or faulty master cylinder or caliper piston (wheel cylinder). Check the level of the fluid in the master cylinder and then examine all of the lines and both calipers (or all four if installed) to see if there is evidence of fluid leaking. Check also the bleeder screws (C) on both calipers to be sure one of these has not come open. Loss of the power braking portion of the system will not result in complete loss of braking under most circumstances. One possible cause which may not be a part of the disc portion of the braking system is that the drum brakes on the rear wheels could go completely out of adjustment.

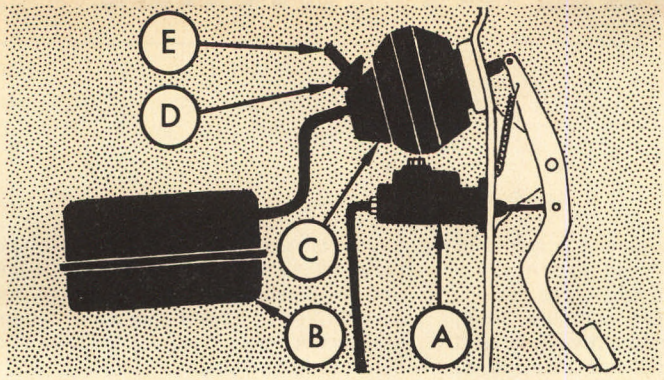
BRAKES HEAT UP AND FAIL TO RELEASE

This may be caused by caliper pistons that have seized due to overheating, usually after heavy braking while descending a hill. One other cause of this problem is a driver who rides the brake pedal with his foot while driving.

UNEVEN BRAKING ACTION

This is due to roughly the same set of reasons as pulling to one side. Seized pistons, fluid or grease on pads, proportioning valve malfunction or caliper misalignment can all cause this problem.

TROUBLESHOOTING POWER BRAKES



A power brake-equipped car has all the normal brake equipment of a non-power brake car, plus the power booster which steps up the braking force supplied by the driver. This is done by utilizing engine vacuum in much the same way it is used to run windshield wipers and regulate ignition advance. The master cylinder (A) is internally the same as non-power master cylinders. The power components are the vacuum reservoir (B), which provides boost as long as the engine is running, and the control valve (C).

The system works like this. The control valve senses the pressure of the driver's foot on the pedal, then triggers the vacuum boost in proportion to the brake pedal pressure and travel. The vacuum reservoir "stores" sufficient vacuum force to permit several safe stops with the engine off, preventing loss of effective braking in case of engine failure. In case of vacuum failure, the braking system does not fail completely, but pedal pressures required to stop become quite high.

To troubleshoot the power brake system, first road test the car to make sure that the rest of the brake system is working. Stop the car at about 20 mph and note whether the car stops smoothly and in a straight line. If the pedal has a spongy feel, the hydraulic portion has air in the system.

With the engine shut off, place the transmission in neutral. Depress the brake pedal several times to bleed off any vacuum stores in the system. Hold a light pressure on the brake pedal and start the engine. If the vacuum system is working and building a vacuum, the pedal will move up under your foot, and less pressure will be required to hold the pedal in the applied position. If no pushing action on your foot is felt, the system is not working. Stop the engine and press on the pedal several times to deplete any remaining vacuum, then hold the pedal firmly down. If the pedal moves away (toward the floorboard) under your foot, the hydraulic portion of the brakes is leaking or the master cylinder is allowing fluid to seep around the seals inside.

Start the engine again. Leaving your foot off the brake, run the engine rpm to a medium speed and turn off the ignition. At the same time remove your foot quickly from the throttle pedal. This preserves the buildup of engine vacuum. Wait about a minute, then try the brake action again. If there is not sufficient brake vacuum for three or more applications of the brakes, the vacuum check valve (D) between the vacuum storage unit and the engine is faulty and is leaking vacuum back to the engine.

HARD PEDAL

High pedal pressures indicate failure of the system to maintain vacuum for brake boost. Make a check of the external surfaces of the vacuum control valve (C) and examine the vacuum line running from the engine to the storage reservoir for cracks or leaks. (Consult the shop manual for location of all components, as they vary widely from one car to another.) All other problems are internal to the unit and should be checked by a qualified mechanic.

PEDAL GOES TO FLOORBOARD

This could be caused by either the basic brake system or the power portion of the brakes. Again, check the master cylinder fluid level and go over all external portions of the brakes, checking for fluid leaks. (See also the section on non-power brake troubleshooting dealing with this problem.)

BRAKES WILL NOT RELEASE

This means that the check valve in the power brake system is jammed or some other part of the power booster unit has locked up and is keeping braking power on the system. It is sometimes possible to disconnect the vacuum line from the engine (E) to the brake system. Then carefully drive the car to a mechanic.

CAUTION: BE CAREFUL WHEN DRIVING WITH THE BRAKE VACUUM LINE DISCONNECTED, AS BRAKE EFFECTIVENESS IS REDUCED.

Trailer Brakes–Electric & Hydraulic

While trailer brakes stop the vehicle in the same way as auto brakes (expanding shoes against a drum), the method in which they are actuated differs. As no one has yet been able to devise a safe and certain way of teeing in and out of a hydraulic line at will to enable trailer brakes to work in conjunction with the car's brakes off one master cylinder, this method most obvious to beginners is not used. Instead, two other braking actuation systems have been developed—electric and hydraulic, each with its own advantages and disadvantages. Although neither seems to be basically better, electric brakes appear to be more popular in use.

ELECTRIC BRAKES

These are really quite simple, using two additional components beyond those with which you may already be familiar—an electric control box, whose signal sets the trailer braking action in motion, and an "electric wheel cylinder" which replaces the usual wheel cylinder and consists of an electromagnet linked to the brakes and a rotating armature mounted on the brake drum. The more current passed into the system by the control box, the harder the resultant braking action.

When the electromagnet is energized by the control box signal, it tries to stop the armature passing by. As the armature pulls the magnet (which is linked to the brake actuating lever) in the direction of wheel rotation, this forces the primary shoe into contact with the drum, which brings the secondary shoe into play. Once the magnet has followed as far as the lever's travel will allow, it slips around the armature.

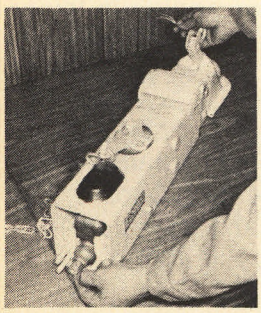
Control boxes vary from the completely automatic (which uses a hydraulic slave cylinder connected to a variable resistor that causes hydraulic system pressure to reduce circuit resistance when the car's brakes are applied), to the fully manual (which does the same thing but is operated by the driver). Depending upon their type, control boxes are located on the steering column, under the hood or beneath the floorboard, but all are powered by the car's battery. Excessive wire length, use of wire that's too light, or a low battery can all reduce braking efficiency, as can an excessively worn electromagnet. Periodic maintenance is suggested at approximately 5000-mile intervals.

HYDRAULIC BRAKES

Hydraulic trailer brakes work in the same manner as those on your car. Line pressure from the tow vehicle is transferred through a hydraulic coupling device without transferring the actual fluid. Such couplers contain their own master cylinder, as well as a slave cylinder that ties into the car's hydraulic line. When the car brakes are applied, hydraulic line pressure reacts against the slave cylinder, which activates the trailer's master cylinder, causing the individual wheel cylinders to move the brake shoes into contact with thefidrum.

A variation on this theme, the surge brake system is found increasingly on light trailers. A surge brake controller replaces the conventional coupler and as the tow vehicle slows down, the trailer's momentum "surges" against the controller, activating the trailer's master cylinder. The greater the rate of deceleration, the harder the trailer brakes are applied.

Surge braking systems do not allow individual braking of the trailer, will not permit trailer brakes to be set when stopped on uphill grades, and can cause problems when backing up, as the backing motion itself may actuate the brakes when not desired. Hydraulic trailer brakes are serviced in the same manner and intervals as conventional automotive brakes, with their lifespan dependent upon the same factors.



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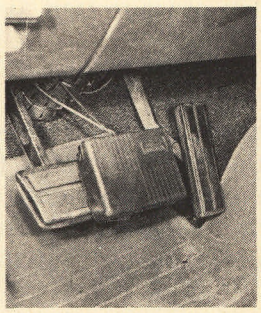

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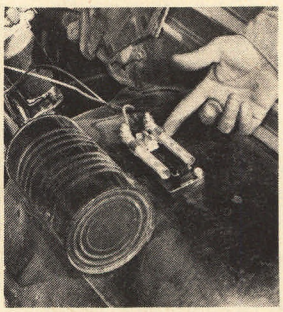

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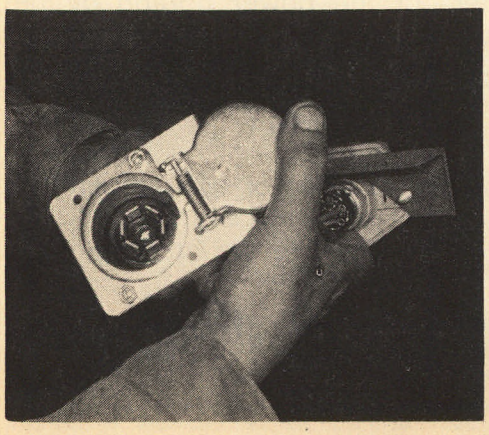
1. This Dico unit is typical of trailer hitches using the hydraulic "surge" brake system. The master cylinder at the back connects to the trailer's hydraulic system; when the tow vehicle slows down, the weight of the trailer activates the hitch cylinder and thus the trailer brakes.

2. This is the Warner control unit used with an electric braking system. Mounted on the car's brake pedal, it's fully automatic. Instead of placing your foot on the brake pedal to slow down, you step on the control unit.

3. This is the device that controls the rate at which the electric brakes are applied. Moving the clamp toward the front of the springs increases the distance the electrical signal must travel and thus you can adjust the trailer brakes to come on slightly ahead of, at the same time as, or slightly after the car's brakes begin to work.



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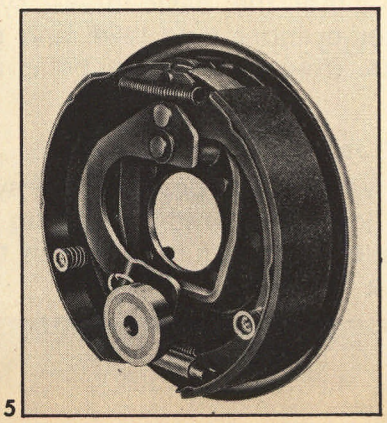

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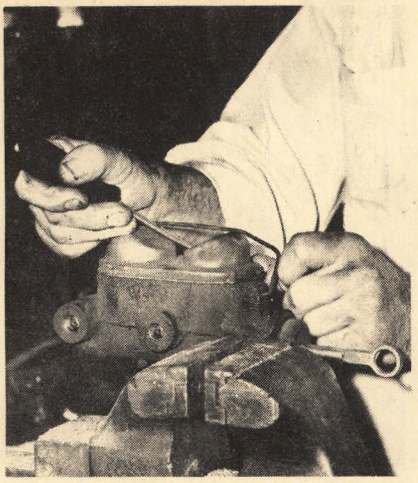
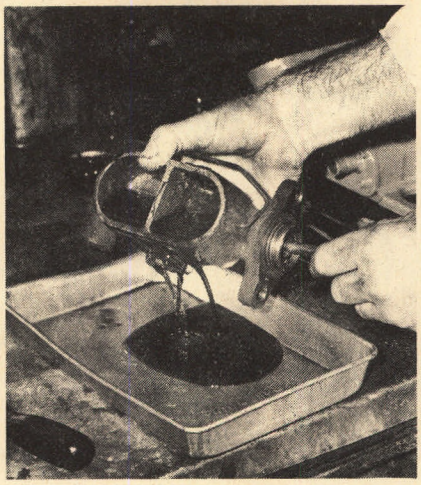
4. This socket box unit is mounted at the rear of the tow vehicle and is the only connection required to hook up the trailer's electric braking system to the car. This six-pronged female receptacle type is the most durable and is favored by many users.

5. The latest design advance in electric brakes is this spot-magnet type from Warner Electric Brake. Featuring simplified construction and installation ease, it's said to lower overall cost of electric braking systems. In this design, the magnet is mounted on the brake lever arm and when energized, it causes contact to the drum surface, which acts as an armature. Such contact forces the brake shoes against the drum, bringing the trailer to a stop.

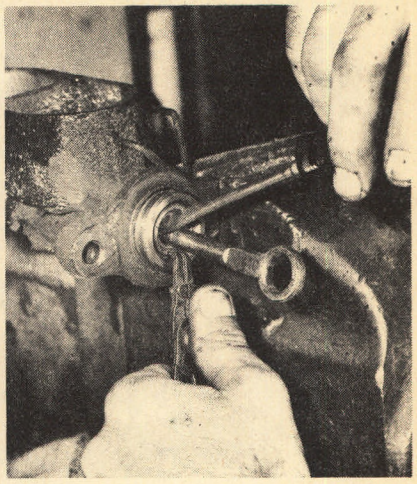
HOW-TO: Master Cylinder Overhaul



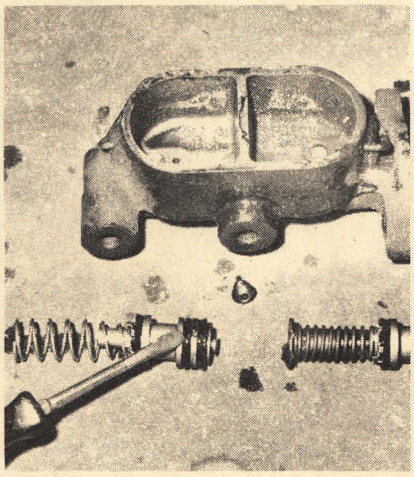
1. After removing the master cylinder from your car, pop the wire retaining spring loose (or remove fastener) so it can be drained.



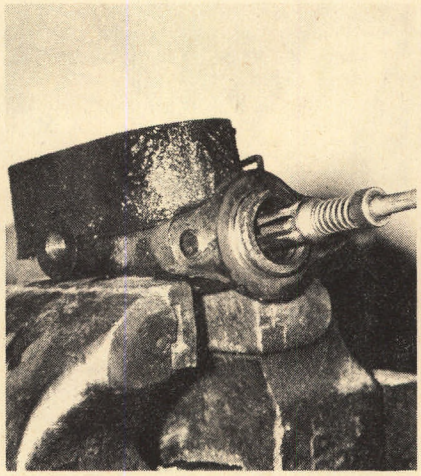
2. All brake fluid should be drained out and disposed of. Never reuse any fluid once it has gone through lines or cylinders as it will be dirty.



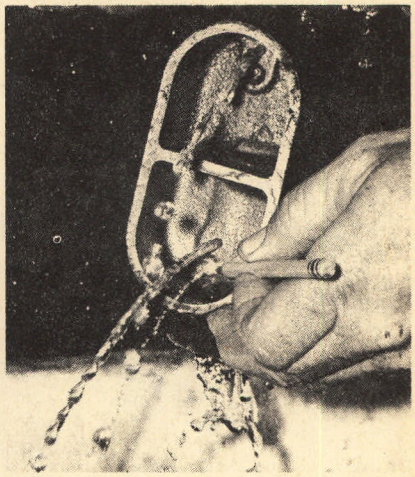
3. Clamp cylinder in vise and remove retaining clip that holds primary piston and pushrod in place. Pull them and secondary piston out.



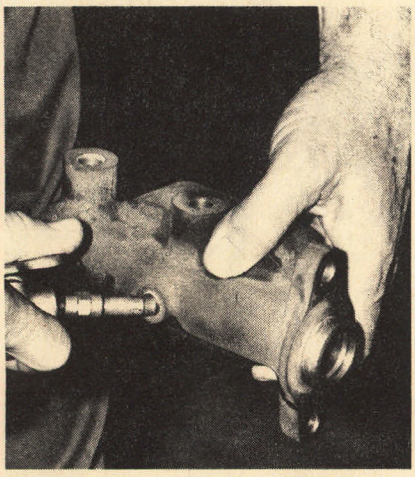
4. Note the sludge that had formed in master cylinder and gathered on secondary piston and return spring; this can cause brake failure.



5. If sludge collection has not damaged cylinder bore, it can be honed lightly to remove glaze and a master cylinder rebuild kit used.

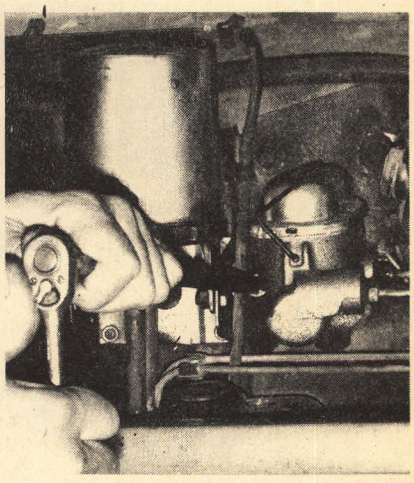


6. Rinse cylinder with alcohol and check to make sure all passages are open and alcohol pours through freely, as illustrated in this view.



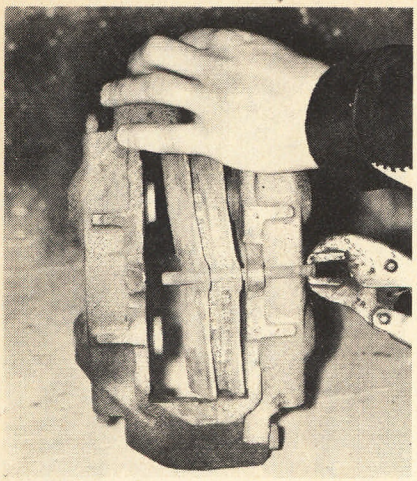
7. Use a high pressure air hose to remove all traces of alcohol from the cylinder and passages, along with any sediment that is still there.

8. Clamp cylinder in vise after pistons are installed. Fill with fluid and pump up by hand to bleed unit. Fluid should pour right out.

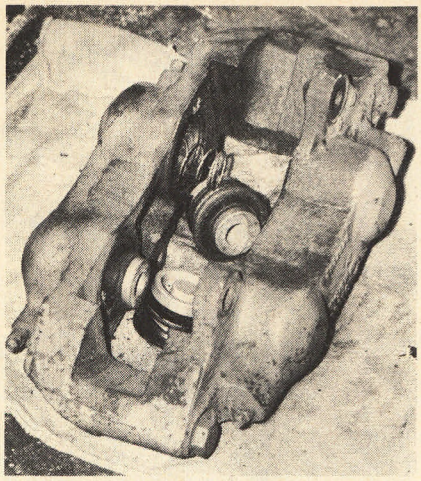


9. Now reinstall unit and hook up lines. Vanowen Brake, 11576 Vanowen St., No. Hollywood, Calif., performed operations shown on this page.

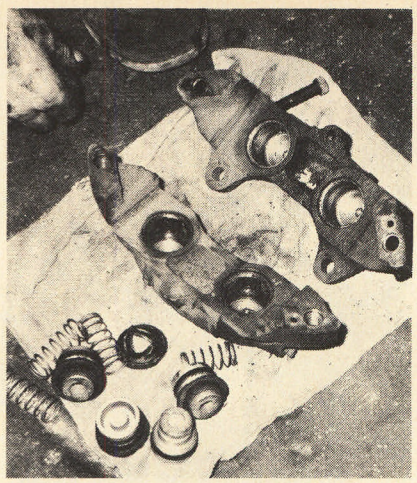
HOW-TO: Disc Brake Seal & Boot Replacement



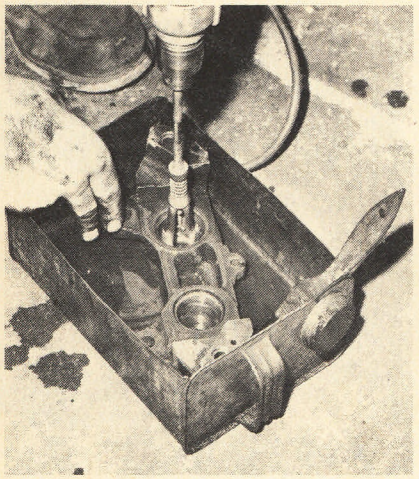
1. After removing cotter pin, then pull retaining pin from the caliper halves. Follow up by removing the brake shoes from the caliper assembly.



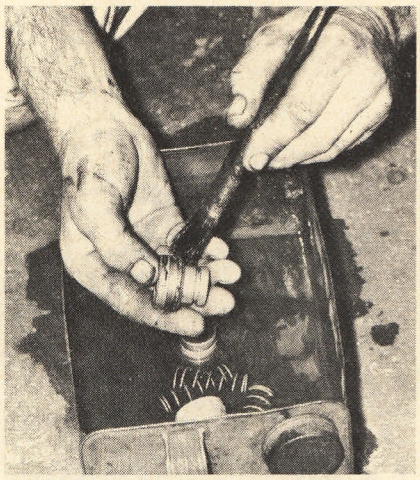
2. An air hose placed against the brake line entrance should pop the pistons free. Two came free here. If not, pry them with a screwdriver.



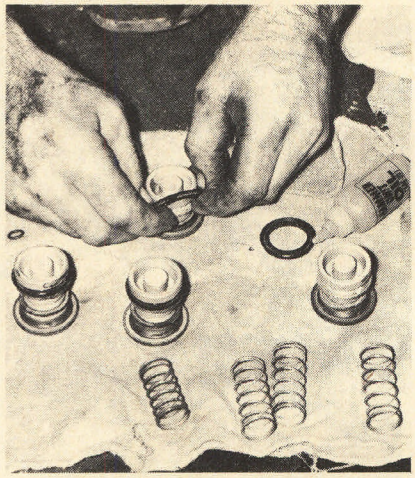
3. Caliper bolts, or retaining bolts, can be removed next. This will allow you to separate the two halves to get at the bores.



4. Clean, denatured alcohol is used to wash brake components. The bores are cleaned up with a super-fine hone within specifications.



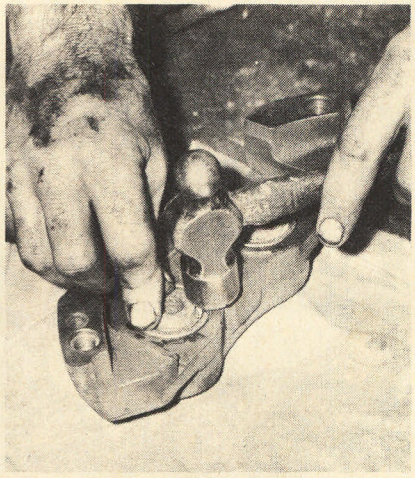
5. Pull old seals and boots from the pistons, wash them carefully. Vanowen Brake & Wheel, North Hollywood, Calif., did this job.



6. Assemble boots on pistons, metal side out, seals with wiping edge (side that is cupped or grooved) out. Use plenty of assembly lube.

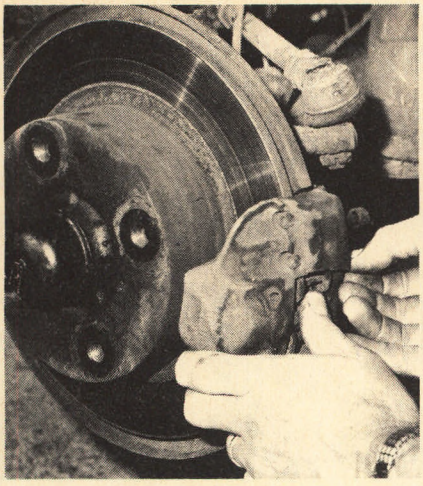
7. After washing in alcohol, parts are washed in water, then air dried. Bores are lubed, as are the seals and boots, then parts assembled.

8. If you haven't a seal installer, ease the wiping edge of the seals into the bore with a tiny screwdriver, moving it about the edge.

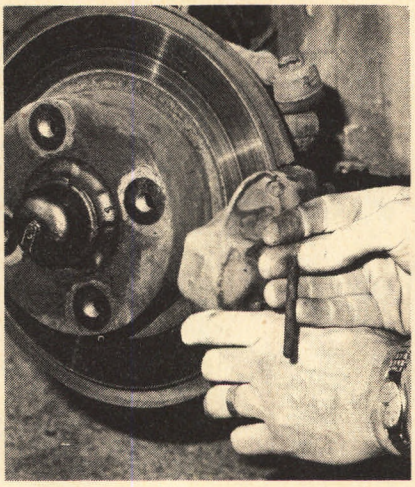


9. A small hammer is used to tap about the metal edge of boot, seating it in the bore. Now install shoes, retaining pin, cotter pin.

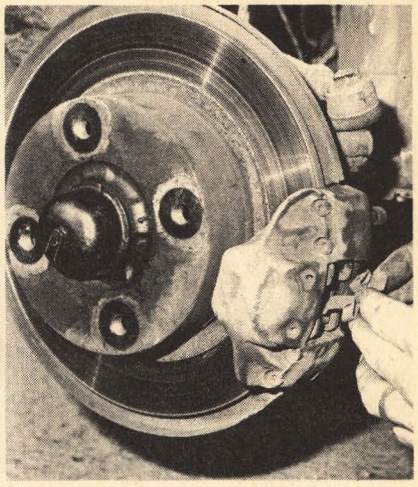
HOW-TO: Disc Brake Reline



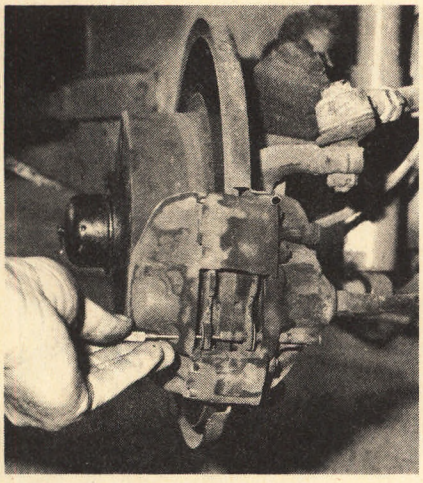
1. To reline disc brakes on a 1500 VW wagon, depress cross spring clip, drive upper pin loose with a punch, then remove same by hand.



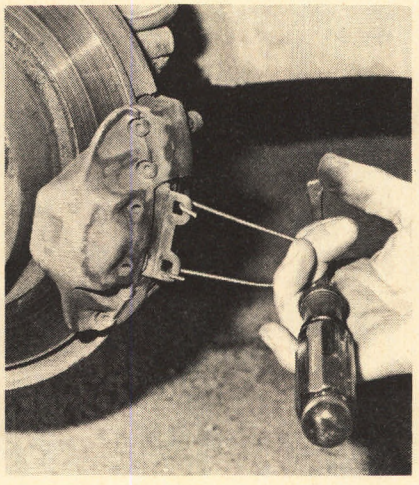
2. Pin comes out easily. Note that one end of the pin is split. When reinserting the pins, be sure that the split end faces toward car.



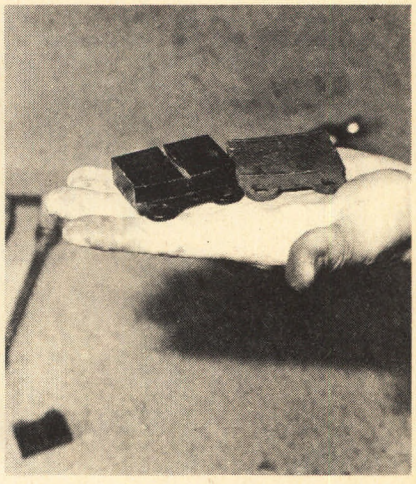
3. Depress the cross spring clip again, then angle the clip up and over the bottom pin and out. The first may be hard, others easy.



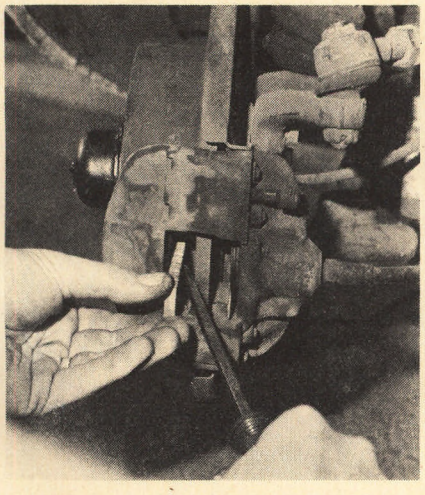
4. Now drive the lower pin free with a punch the same as the upper, and remove same. They are tight enough that you can't use a pair of pliers.



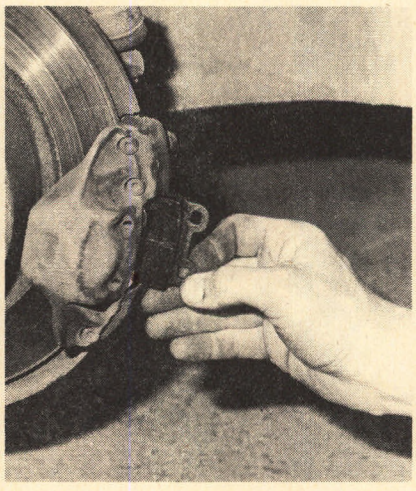
5. Make up a pad remover from a coat hanger. Make sure you don't remove the piston shield which has same kind of ends, but the pad itself.



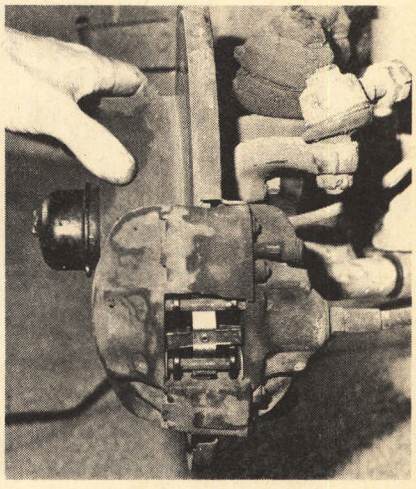
6. The pad on the right has 45,000 miles on it and really shows the wear. For a few bucks and a few minutes, you'll have new brakes.



7. Remove some fluid from master cylinder, then use a piece of aluminum to return self-adjust piston back to original position. Install pads.

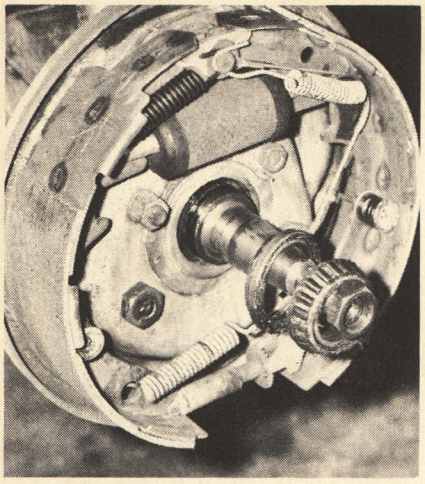


8. Once the self-adjust pistons are moved back, insert the new brake pads into the caliper, pushing them all the way into the housing.

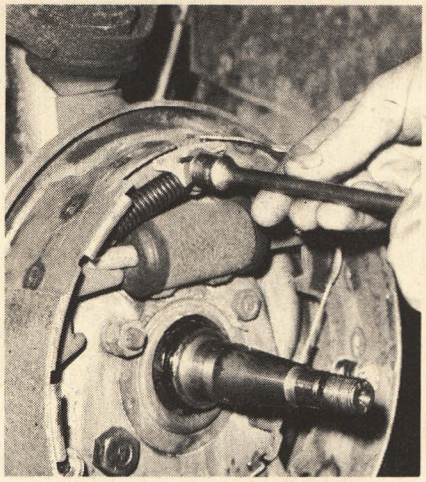


9. Angle the new cross spring clip into position, install upper pin. Rotate disc to make sure it's free, then go ahead and install the lower pin.

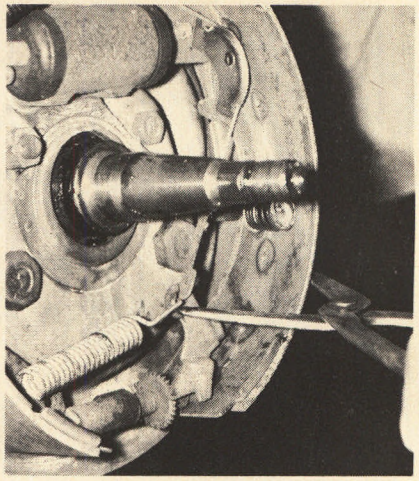
HOW-TO: Wheel Cylinder Overhaul and Shoe Replacement



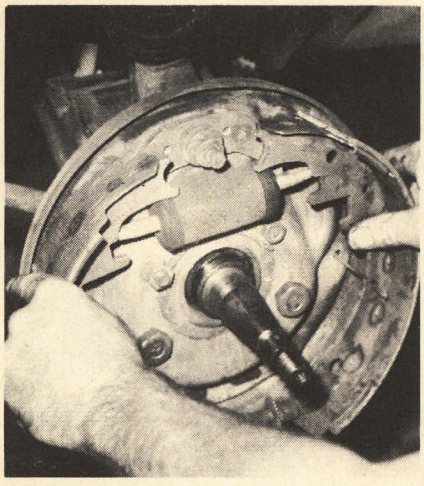
1. Remove outer wheel bearing, then replace nut so it can be used to pull seal from drum without damage. This step will work with roller bearings, but will ruin seal with ball bearings.



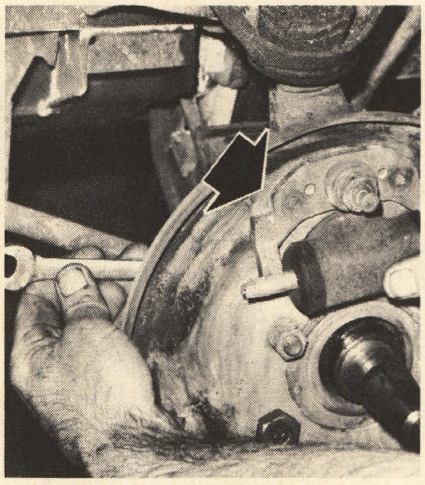
2. With the brake drum removed, the first operation towards rebuilding the brakes entails removing the secondary (rear) brake shoe return spring with brake tool.



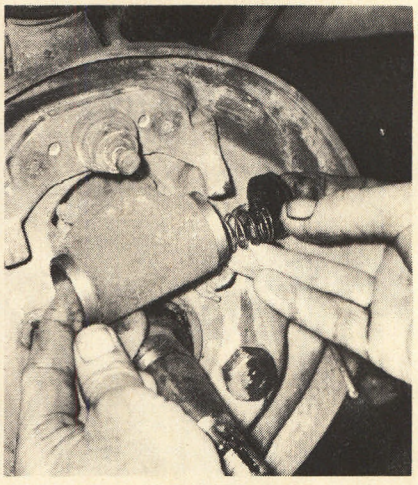
3. Brake spring pliers are used at the bottom to remove brake shoe adjusting spring. Vanowen Brake, 11576 Vanowen St., No. Hollywood, Calif., performed these operations.



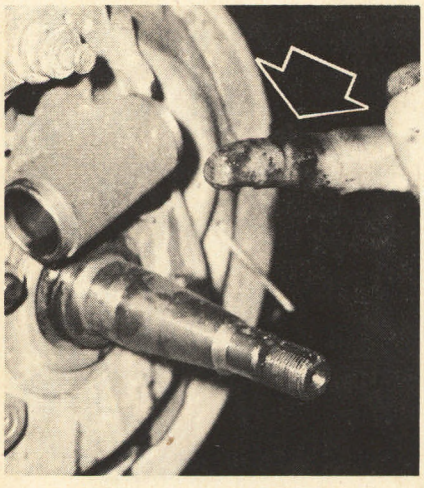
4. The primary (front) brake shoe spring and self-adjuster cable are removed, then the secondary shoe hold-down spring. Now the shoes can be removed from backing plate.



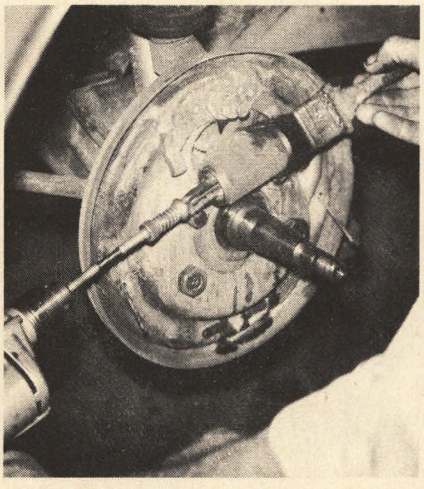
5. Remove wheel cylinder hold-down bolts. Bracket shown (arrow) keeps cylinder from coming apart should some part fail during operation. Car being repaired is a late Dodge.



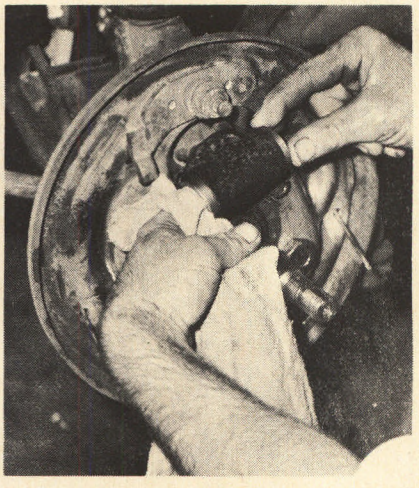
6. Dust boots at each end of the wheel cylinder are removed, along with push rods and pistons. Now the wheel cylinder cups and cup expansion spring can be removed.



7. Physical evidence of sludge accumulation in one wheel cylinder after only 30,000 miles. Each wheel cylinder, the lines, and master cylinder are also contaminated.

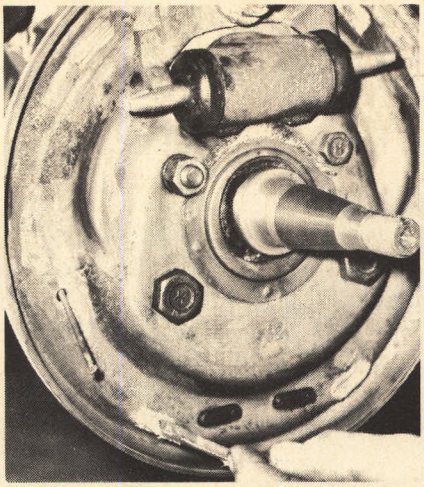


8. Denatured alcohol is used with a fine hone in refinishing cylinders. Mike cylinder bores. Maximum overbore allowable is .003-in. After that, new wheel cylinders must be used.

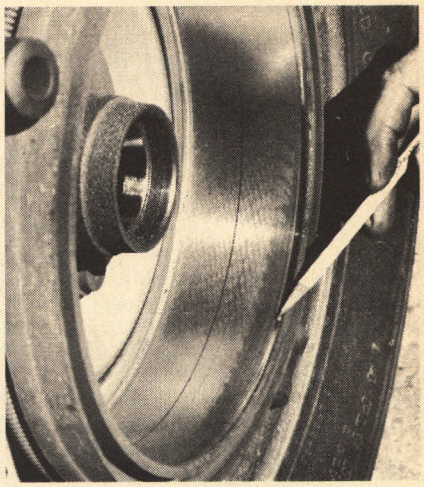


9. The cylinder bore is wiped clean with a lintless cloth after honing and washing with alcohol. Alcohol cuts brake fluid, doesn't leave a residue, and doesn't harm the boots.

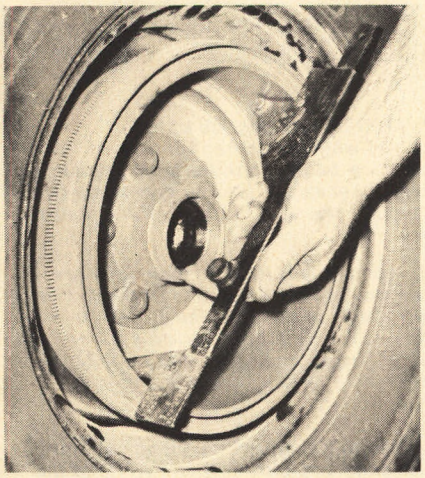
10. All internal cylinder parts are coated with an assembly lube, not brake fluid. Assembly lube will not mix with brake fluid, and will protect parts from any undue wear.



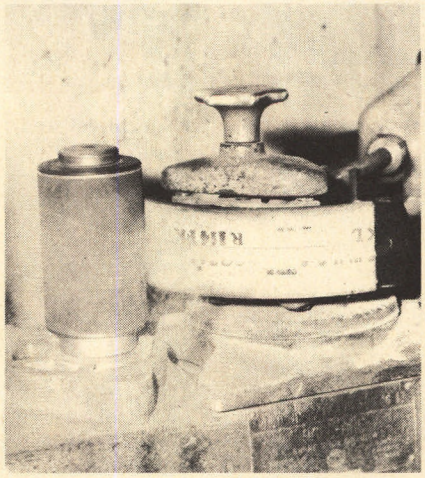
11. Assemble wheel cylinder pieces, then lube brake shoe backing plate platforms and the star adjuster screw with some Lubriplate. This is to reduce wear, help in adjusting.



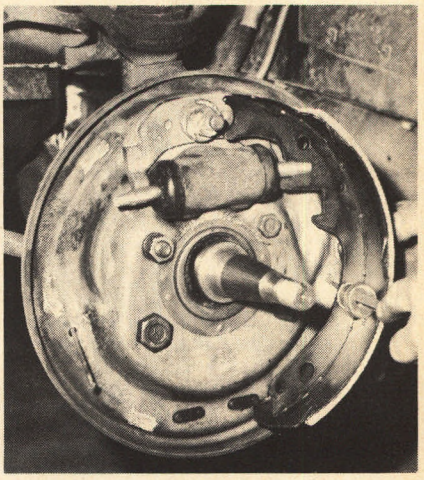
12. The drum grinder used at Vanowen features both a cutting tool and fine grinding wheel. After removing .008-in. from this drum, note groove and low spot, illustrating drum wear.



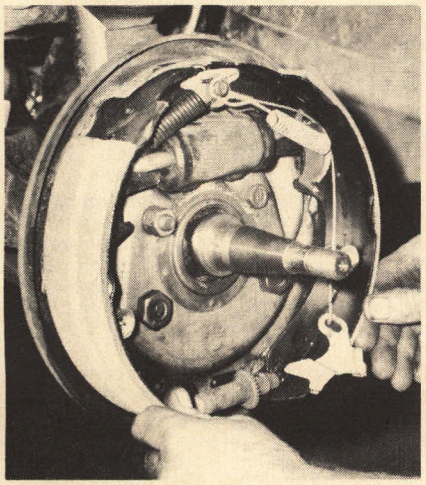
13. So, a second pass on the drum lathe was performed, removing all low spots and grooves. A drum gauge is used to mike inside of drum. If it measures too big, it must be replaced.



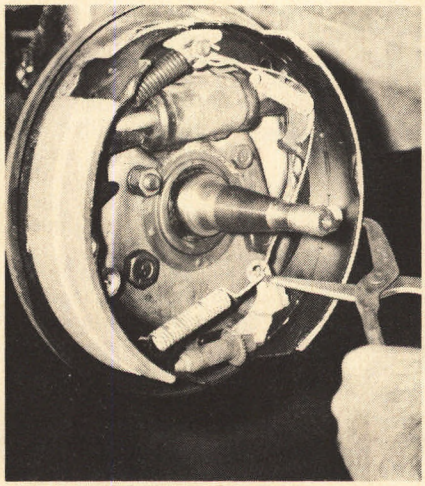
14. After cutting a groove in these new Bendix linings, to aid in cooling, shoes are arc ground so their radius coincides with that of the brake drum radius that has just been cut.



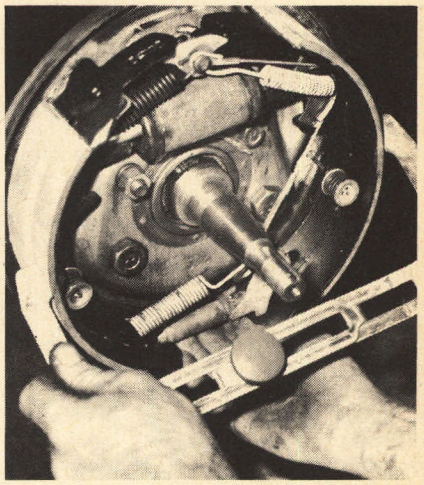
15. After blowing off all dust, the new rear shoe is slipped behind the wheel cylinder push rod and the shoe hold-down spring and clip are engaged in the brake backing plate.



16. The primary shoe and shoe-to-anchor spring is attached, then the secondary spring, cable guide and star adjusting wheel are replaced. Brake rebuild job is nearly done.



17. Using your special brake spring pliers, install the lever return spring and hook the self-adjusting cable lever up with the secondary brake shoe. These pliers are a must.



18. The brake adjustment gauge is first used to measure the drum I.D., then fit about shoes until they touch the gauge. Star adjuster is backed off three or four notches.

Suspension & Alignment

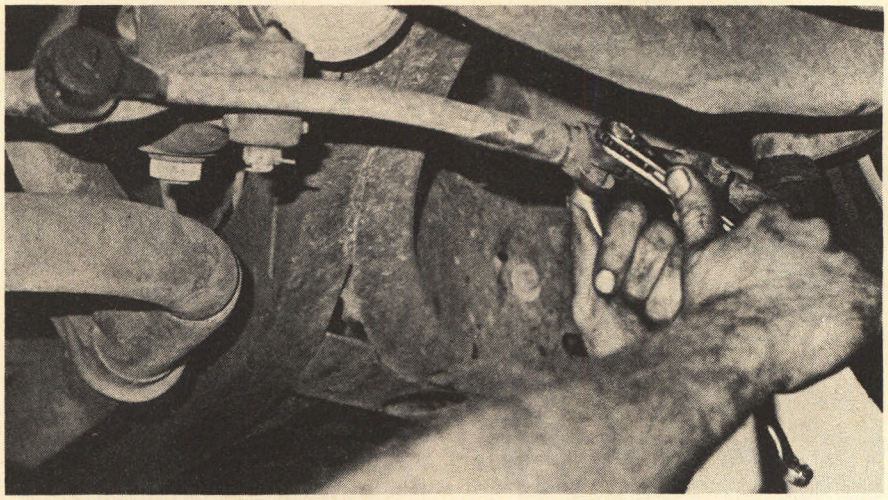
After so many years of automobile development it seems that by this time the suspension system should have reached a point where one basic design is admittedly the best, and everyone uses it. There is a certain amount of similarity in that most cars use independently suspended front wheels and a solid rear axle, but that's about the only statement you can make that applies to all American suspensions. The little engineering differences that separate one suspension from another are enough to change not only the ride and handling characteristics of the car, but also the way in which alignment is maintained.

Most of us, when considering alignment, think of tire wear, because this is the place where incorrect alignment shows up first. A unicycle doesn't have any problem with wheel alignment or tire wear because one wheel can go anywhere it wants to, but when you get four wheels tied together on an automobile, then they all have to work together. If not, one or more of them is going to be pushed slightly sideways as it rolls down the road, which scuffs rubber off the tread and can make a baldy out of a nobby in a few thousand miles. Alignment also affects the steering and handling of the car. If the wheels are not going down the road in a straight line, it's reasonable to assume that the car is not going to be as responsive as it should be when the driver tries to make it go where he points it.

ALIGNMENT BASICS

Factors involved in front-end alignment (and in some cases, rear-end alignment) are toe-in or toe-out, caster, camber and kingpin angle. Another factor in front-end alignment is known as "Ackermann," from the term Ackermann Principle in which the inside wheel of a car in a turn cuts a sharper angle so that each wheel follows the circumference of a correct circle, the inside wheel scribing a smaller circle than the outside wheel. This is a built-in effect and is a function of the relationship of the steering arms and drag link or the tie-rod and is not normally adjustable on any car.

Toe-in or toe-out describes the relationship of the front wheels to each other when the steering is in a straight-ahead position. In the average car there is a slight toe-in; in other words the front edges of the front wheels are closer together than the rear edges by roughly ⅛-in. It isn't much, but the effect is to keep all the steering linkage in tension, keeping any slop out of it in the straight-ahead driving position where no cornering forces are present to keep things taut. Toe-out is the opposite effect and is found, other than in a faulty system in the straight-ahead position, only in certain front-wheel-drive cars. Naturally, due to Ackermann effect, there is a toe-out in the turn position.



1. Wheel Alignment and Adjustment

Caster is the effect formed by the inclination of the top of the kingpin or upper ball joint to the rear which imparts an action similar to a furniture caster in keeping the wheels headed in a straight line. You'll see this condition grossly exaggerated in a dragster or Bonneville-type straightaway record car. In the average passenger car this angle is 1° to 3° off a vertical line. On earlier cars with solid axles it is as much as 7°.

Camber, which is referred to as either negative or positive, is the inclination of the wheels inward or outward at the top; in other words, leaning into or away from the car. Earlier cars, meant for use on high-crowned roads, had quite a bit of positive camber (leaning out) to bring the tires perpendicular to the road surface. More recent cars have little or none, and some of the later high-performance cars have from 1° to 2° of negative camber to aid in cornering by offsetting the tendency of a tire to roll under in a turning situation.

Kingpin angle or kingpin inclination is now known as steering axis inclination because modern cars do not have kingpins. The steering axis is an imaginary line that intersects the centers of the ball joints. The angle that this imaginary line makes with the vertical is called the steering axis inclination. If kingpins were used, the steering axis would coincide with the axis of the kingpin itself. A theoretically perfect axis inclination would intersect with the road surface exactly at the center point of the tire's contact with the road. In that theoretically perfect condition the tire would merely

1. Most drivers pay little attention to wheel alignment until their tires are badly worn. Periodic adjustment checks are inexpensive when you compare them to the cost of premature tire wear.

2. Independent front suspensions are responsible for the demise of early drag link steering designs like No. 6. Note that with all the split tie-rod systems, toe adjustments must be made equally on each side to keep the steering wheel centered.

3. Without kingpin inclination, we have the condition on top which will pull the steering wheel right out of the driver's hands when he steps on the brakes. Note that when kingpin inclination line and tire and wheel center do not intersect at the road, the measurement they are apart is called the scrub radius.

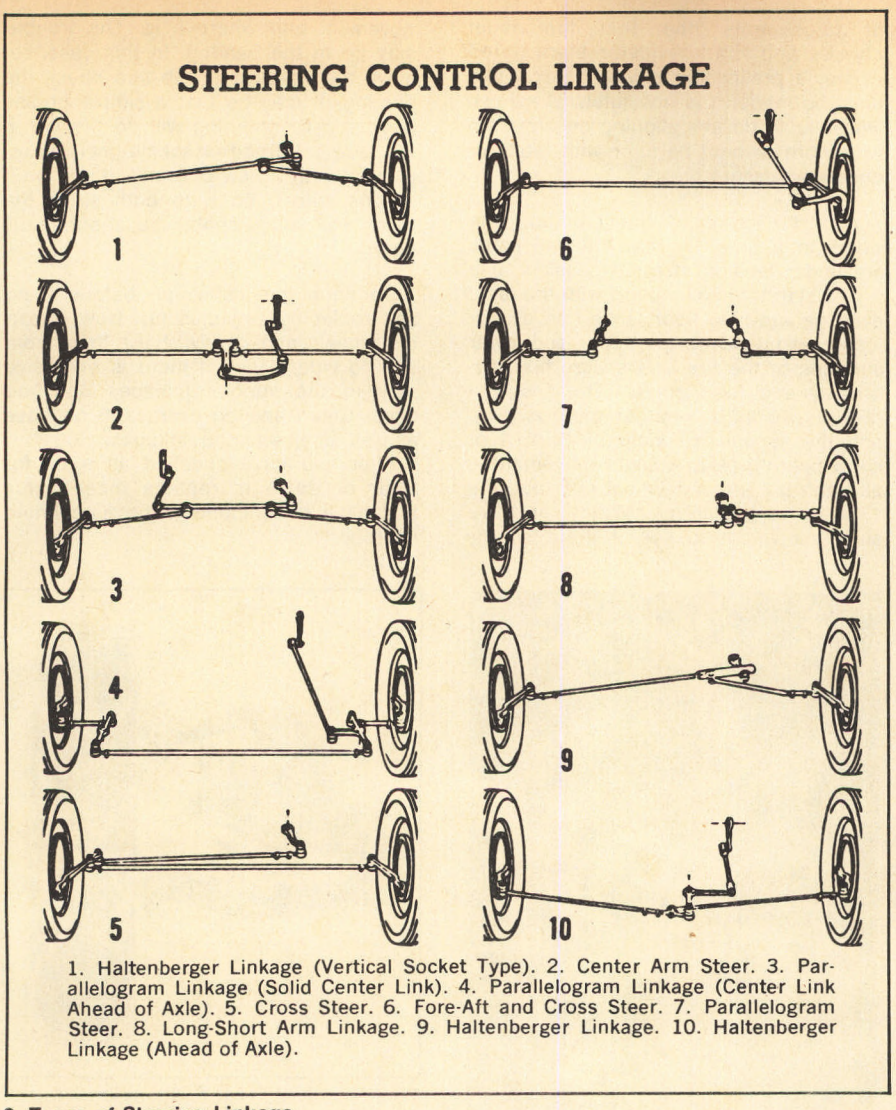
4. Positive camber exists when top of tire is tilted away from the car, negative camber when the tire is tilted toward the car. Early-day cars had considerable camber to compensate for the high-crowned roads of the day.

5. The inside wheel has to turn more than the outside. If the wheelbase were longer, you would have to turn the front wheels more to get the same turning radius. The size of wheels and tires and the width of the frame limit how much the wheels can turn.

6. Most modern cars with independent front suspension use A-arms. Shims are used at the A-arm mounts to set front end alignment.

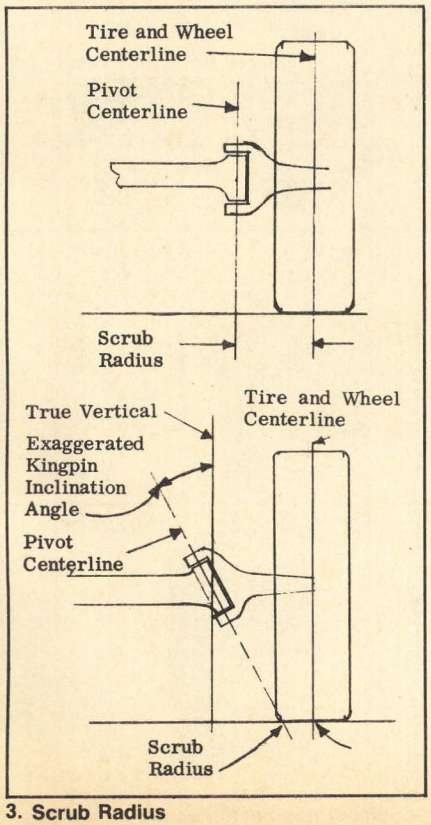
7. Removing the shim from one side of the upper control arm will give more positive caster.

8. Starting out with four shims on each side, we want to change the camber without changing caster.

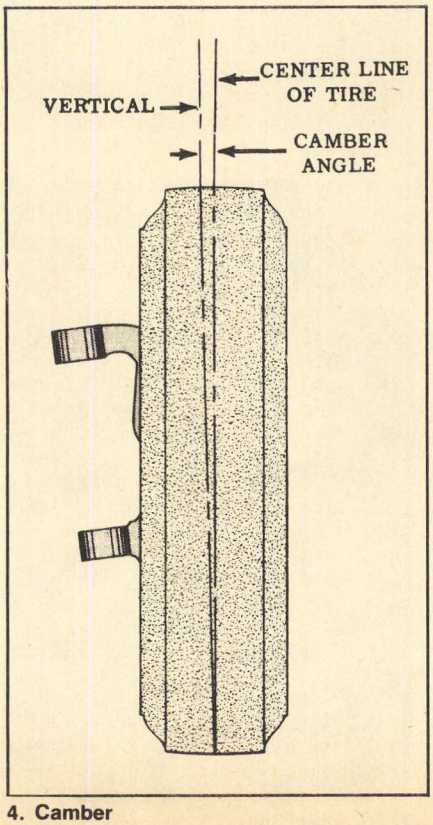


1. Haltenberger Linkage (Vertical Socket Type). 2. Center Arm Steer. 3. Parallelogram Linkage (Solid Center Link). 4. Parallelogram Linkage (Center Link Ahead of Axle). 5. Cross Steer. 6. Fore-Aft and Cross Steer. 7. Parallelogram Steer. 8. Long-Short Arm Linkage. 9. Haltenberger Linkage. 10. Haltenberger Linkage (Ahead of Axle).

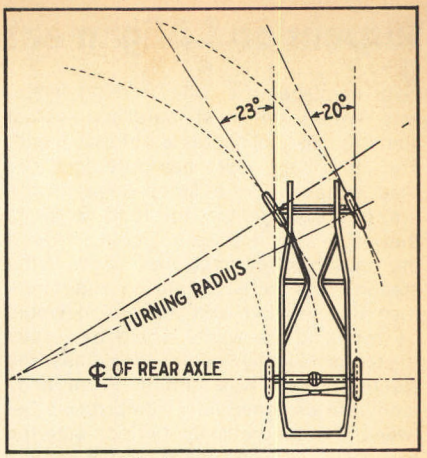
2. Types of Steering Linkage



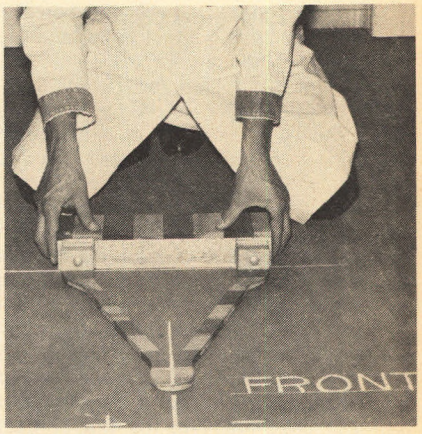
3. Scrub Radius



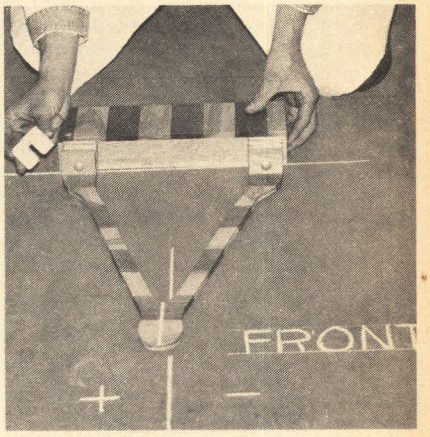
4. Camber



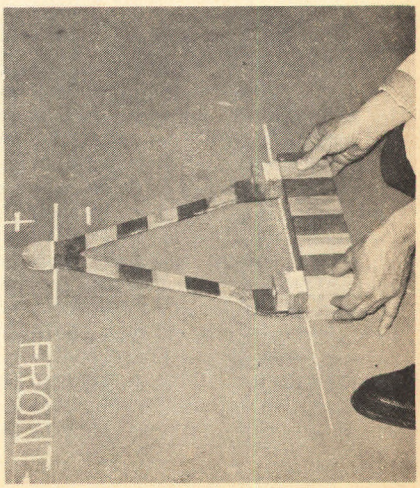
5. Turning Circle



6. A-Arm Front Suspension



7. Positive Caster



8. Changing Camber

pivot in place when the steering wheel was turned. In most cars the actual steering axis inclination is not that much. The imaginary line may intersect the road surface at the inner edge of the tire, or it may contact the road so far to the inside that it does not coincide with the tire's road contact area at all. If the steering axis were straight up and down, then the steering axis inclination would be zero and the wheel would be forced to rotate slightly every time that the steering wheel was turned. Front ends today are designed as a compromise between the theoretically perfect steering axis inclination and the perfectly vertical steering axis.

The actual measurement between the center of the tire's contact patch and the point where the steering axis hits the road surface is called the "scrub radius." An attempt is made to keep the scrub radius as small as possible when designing front ends so that steering and handling will not be affected too much.

Wheel offset has a big effect on how a car steers and handles because it changes the location of the tire's contact patch. If a wheel is offset to the inside more than stock, it moves the tire's contact patch to the inside so that it coincides with the steering axis. This would probably make it easier to steer the car when parking. If a wheel is installed that has less offset—moving the tire contact patch to the outside of the car for more scrub radius—steering effort would probably be increased. All of these things are figured out very carefully by the manufacturer when he designs the front end. When buying a wheel in a wrecking yard, you should not only look at the bolt circle and the fit on the hub, but also measure the offset. Just because the wheel will bolt onto the hub doesn't mean that it's the right one for the car.

TIRES TELL THE TALE

The first place to check for faulty suspension or alignment is the rubber on the front wheels. Discounting oddball wear that comes from under- or overinflation, check to see if the tires or one tire is worn more on one side than the other; if so, then toe-in of one or both is off. If it is only one that is off, it will show in steering on the road with a definite pull to one side or the other. If both are out of adjustment, tire wear and hard steering in either direction will occur. Tire cupping—an undulating, scalloped wear pattern—can be the result of poor shock absorbers, one wheel out of alignment, a bent spindle, or, what is more likely, a combination of these possibly complicated by loose-tie rod ends which can be caused by misalignment. As a matter of fact, misalignment can, in time, trigger a whole series of ailments and rapid wear. A car that is kept in alignment—with proper tires, good shock absorbers and periodic lubrication—is practically wearproof; but neglect one item and a chain reaction is inevitable.

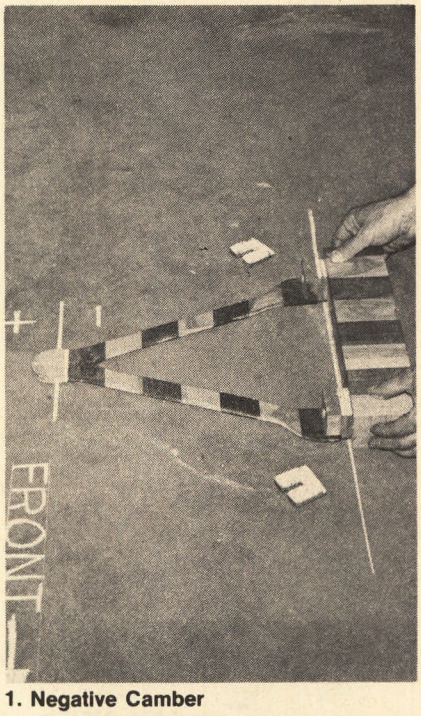
CHECKING WORN PARTS

Before making any alignment checks or adjustments other than the visual checks and road behavior tests noted above, a preliminary physical inspection must be made. It is absolutely of no use whatever to do any aligning on a system with worn or bent parts or with faulty or unequal-pressure tires.

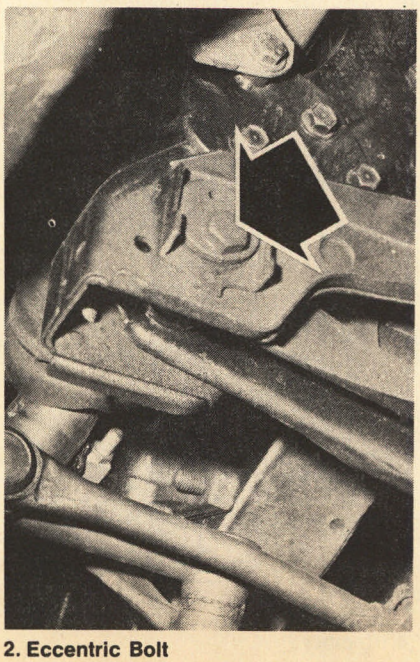
Jack the front of the car up, one wheel at a time, so that the ball joints are under tension. If at all possible, use a jack stand in conjunction with the jack; even garage-type floor jacks can slip or lose pressure. Grab the upper and lower surfaces of the tire and shake, first vigorously and then gently. The first will give a clue as to whether there is play, and the second will help pinpoint it or show bearing play. A slight movement is all right, but any movement over about a 1/64-in. is too much. Watch or have someone watch to see if there is any movement and where it is. The trouble may be in the bearing. In this case, remove the wheel and hub and check the bearing—it may be that a simple grease pack and retightening will do the job. If the race is burned or seems gravelly, replace it with a new one, and if you do it to one wheel, do it to both, since the other one will probably be about ready anyway.

Continue the inspection before doing any replacing or adjusting. Now, grasp the wheels and *gently* shake them from side to side to see if there is excessive play in the various linkages and rod ends. Clean and go over each of these as well as all steering linkages.

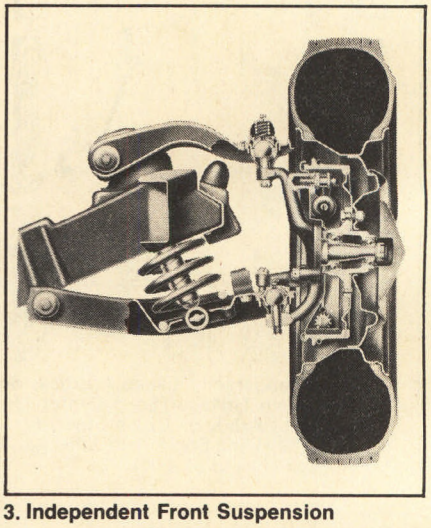
After you have checked all parts for wear or damage, replace those items that have been found to be functioning improperly.



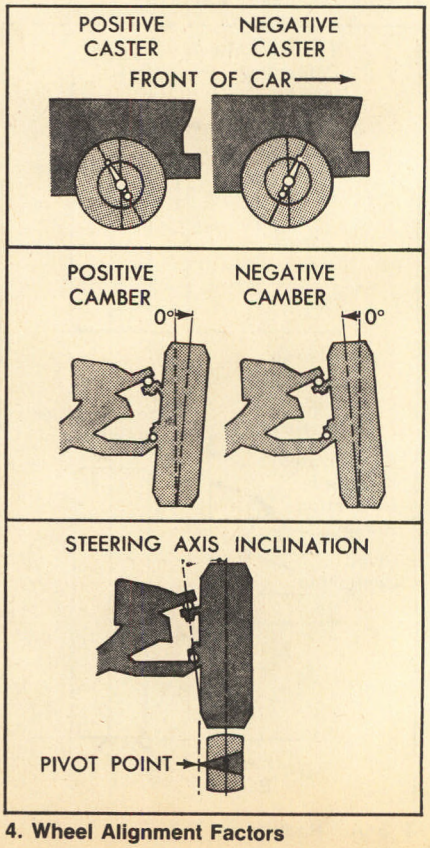
1. Negative Camber



2. Eccentric Bolt



3. Independent Front Suspension



4. Wheel Alignment Factors

BEARINGS

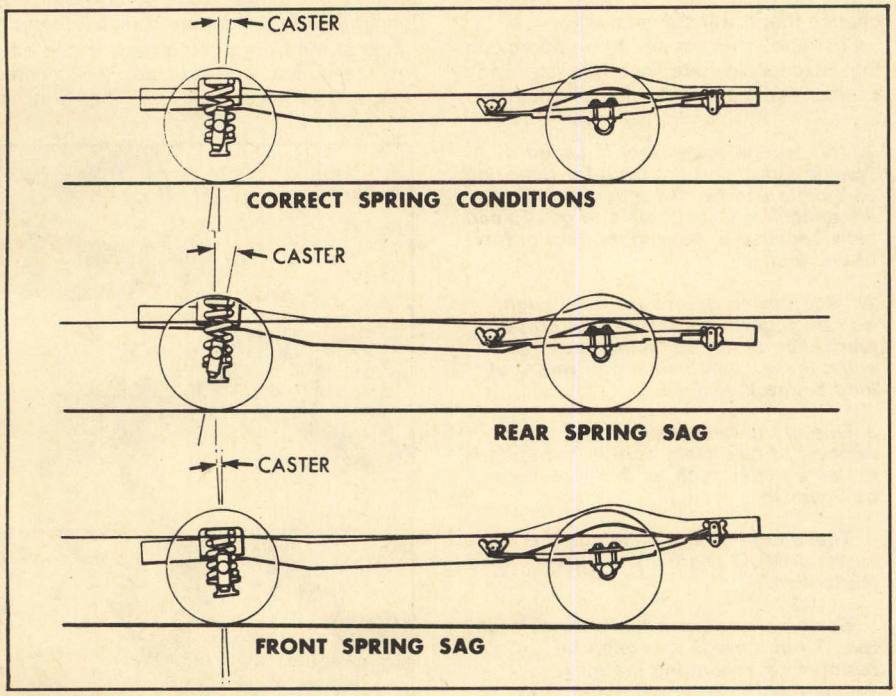
Seldom, if ever, will you find a bearing that will make noise or give any indication that it is bad when you turn the wheel by hand with the car jacked up. A bad bearing will make noise when you're driving the car, but it can be very difficult to tell from which corner of the car the noise is coming. It all boils down to the dirty, time-consuming job of removing the bearings, cleaning them in solvent, and inspecting each ball or roller for pits or roughness. Just one rough roller or ball can sound like a square wheel, so you have to find it, unless you are rich enough to replace all the wheel bearings at once. A clue might be slightly increased play on one front wheel, but don't count on it.

Incidentally, to avoid confusing bearing play with ball joint wear, the car should be jacked up in the opposite way from that for checking the ball joints. In other words, if the spring is above the upper A-arm—as on Ford Motor Co. compacts, intermediates, and Thunderbird, American Motors products, and the Chevy II—the jack should be placed under the lower suspension arm. On those which have the spring *between* the suspension arms, or on cars with torsion bars, the jack should be placed under the crossmember. This keeps the ball joints in tension and allows only the movement at the bearing.

BALL JOINTS

For the next checks, reverse the jacking procedure outlined above; i.e., for cars with springs above the upper arms, jack from the frame or crossmember, and for those with springs between the arms, jack from the lower control arm. In each case use jack stands, since you are going to be doing some vigorous shaking and spending some time underneath the car.

With the car properly jacked for the type of springs involved, two checks are to be made, one for up-and-down play and another for side play. Up and down play, also known as axial or vertical play, should be checked with a long prybar under the wheel and against the ground so you can lift the wheel. Doing the job without a prybar requires a lot of muscle, which most of us don't have. You will find specifications in your factory shop manual for your car. If the specs aren't available, a general rule, suggested by Moog Industries, makers of ball joints and suspension parts, is that any vertical play over .050-in. is too much. However, this is a conservative estimate.



5. Effect of Spring Condition

1. With four shims removed, there is a change in camber to the negative.

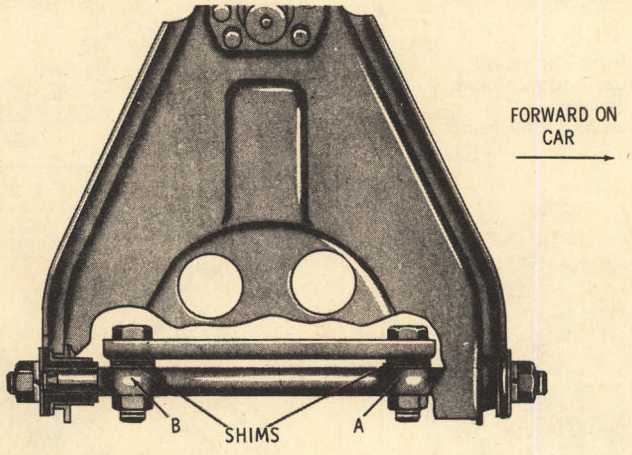
2. This Ford Maverick lower control arm uses an eccentric to align wheel. Just jack up the car, loosen the nut on the other end of the bolt, attach a socket and breaker bar, and the wheel will move laterally in and out as you turn the eccentric bolt.

3. This is the typical, Detroit-type independent front suspension setup. Two pivoting control arms, of unequal length, support the spindle and use a spring-over-shock between the lower A-arm and the frame rail to help in dampening the vertical travel.

4. You can see from these drawings how the factors in wheel alignment will affect handling and tire wear.

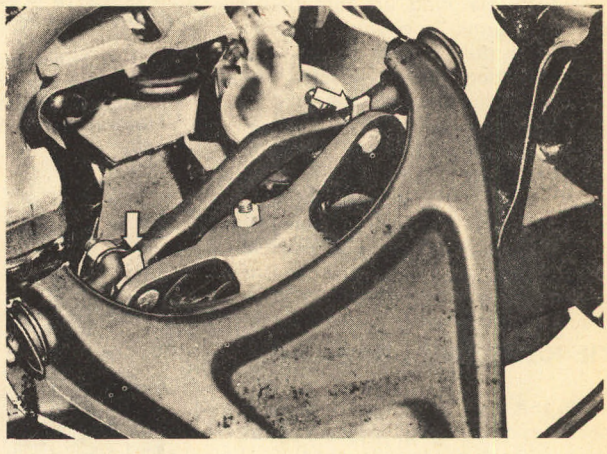
5. Condition of car, especially the springs, has a big effect on wheel alignment. When a car is lowered or raised, it throws alignment off.

6. Control arms are adjusted for front end alignment either by shims or mounting with eccentric bolts.



BY ADDING OR SUBTRACTING AN EQUAL AMOUNT OF SHIMS FROM "A" AND "B", CAMBER WILL CHANGE WITHOUT AFFECTING CASTER ADJUSTMENT.

TO INCREASE CAMBER: REMOVE SHIMS AT BOTH "A" AND "B".



TO DECREASE CAMBER: ADD SHIMS AT BOTH "A" AND "B".

TO DECREASE POSITIVE CASTER: ADD SHIM AT "A".

TO DECREASE NEGATIVE CASTER: REMOVE SHIM AT "A".

6. Shimming for Alignment

In some cases a brand new car will have more than the suggested maximum of .050-in.

In all cases, the joint to check is the load-carrying joint. If the spring or torsion bar pushes against the lower arm, then the lower joint is the one that carries the car weight. If the spring is on the upper arm, then the upper joint carries the load. The other joint just follows along and keeps the wheel pointed in the same direction as the car. Follower joints seldom wear out, but it's a good idea to change them whenever the load-carrying joint is changed.

Some manuals give a specification for side play, but it's difficult to check accurately. Side play, with much vigorous shaking, is what the con man shows you when he wants to sell you a set of unneeded ball joints. If your manual gives a side play spec, then by all means check it. Be sure you aren't picking up play in the follower joint or the steering linkage.

Specifics on replacing ball joints on every car are beyond the scope of this book, since the methods both of removal and of attachment vary considerably from car to car, even in a single manufacturer's line. However, certain general remarks are in order. A great number of cars have ball joints that are held to the control arm by a combination of rivets and bolts in varying combinations. When replacement becomes necessary, the bolts are removed in the normal way, and the rivets must be chiseled off. It is easier if the rivets are drilled first but avoid drilling through and enlarging the holes. The replacement unit will have special bolts included to take the place of the rivets and these, not ordinary bolts, must be used. On some Ford products and some GM cars the ball joints are pressed in, and it is inadvisable for these to be replaced anywhere but in a shop equipped with an arbor press to do the job. Some mechanics are real artists with a rivet gun, used as an impact hammer to force the joint into place when the weight of the car is on it. On Chrysler products the joints are threaded into the control arms, and you will need a special ¾-in. drive socket with at least a 3-ft. handle and lots of muscle. On all cars, getting the tapered ball joint stud out of the hole can really be a bear. Smacking the outside of the hole with a hammer may help, but only if you have tension on the stud. Wedges or screw-type pullers are available at some tool stores. If you can look over the shoulder of a local mechanic while he does a ball joint job, you'll be way ahead.

TIE-RODS AND DRAG LINKS

With the ball joints and bearings checked and found within tolerances or replaced, the next place to check is the tie-rods and links and their ends. Checking consists of visual inspection and manual moving of the linkage. It is best to have another person move the steering wheel while you hold a wheel against it, watching the action of the various links and ends. Some play is inevitable and even desirable, but look for excessive slop that denotes obvious wear. Remember that this play is cumulative; a ¼-in. here and ⅛ there can add up to an impressive total that no amount of aligning will help—in fact aligning is downright futile with a front end that contains more than a minimum amount of excess play. It is also an excellent idea to wash down the linkage with solvent and dry it before trying to make your inspection of grime. It can hide defects and actually give a false "feel" at the various joints. Replace any worn rod ends, checking also for wobble or wear in the tapered holes into which they fit.

ALIGNMENT

Now that everything in the linkage and control departments has been checked and OK'd or repaired, the actual alignment process can be done, with a chance that it will stay that way.

First and foremost, let it be understood that except in dire need, caster and camber settings should not be attempted without a front-end rack. Toe-in settings, on the other hand, are easily done with a minimum of equipment—and that can be homemade.

The first check for misalignment is whether or not the steering wheel is in the straight-ahead position when the car is moving straight ahead. If it is cocked to one side or the other, there is an excellent chance that toe-in is off. Assuming that the wheel has been properly installed in the first place (splined hub only; a keyed hub cannot be installed off-center), the off-center condition will probably be corrected in the alignment process.

By this time, if you have read the foregoing section, you will have noted the construction of the tie-rods and drag links. In most instances the systems will be of two types. In one system, the drag link from the pitman connects with an idler in the center from which relatively long steering links run to the steering arms at the front hub carriers. In the other, the pitman arm attaches to a center link and is matched by an idler arm on

1. This wedge-ended tool is called a "pickle fork," and is useful for removing ball joints and tie-rod ends. Sometimes it's difficult with ball joints to get a solid blow because of the rubber boot at top of ball joint.

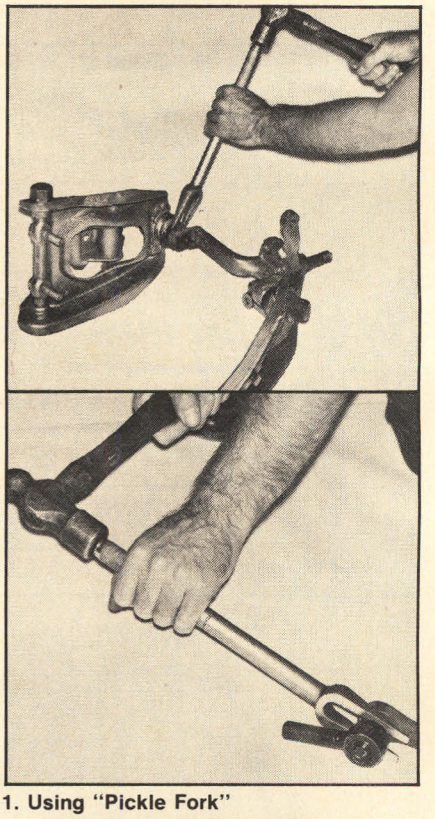
2. "If it moves, grease it." This might well be your motto, for without proper lubrication at the ball joints and tie-rod ends, these components can wear out long before their time.

3. One of the best methods for the removal of ball joints and tie rod ends is to use a puller such as this tool made by Snap-On.

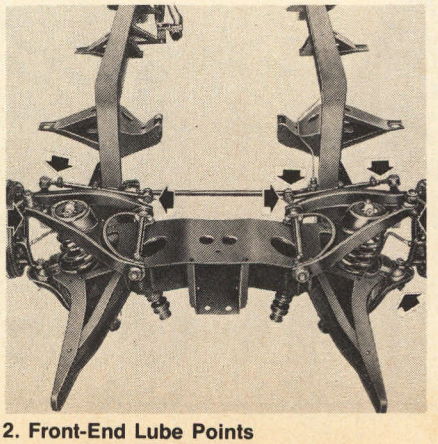
4. These control arm bushings are made by the JAMCO company and never need lubrication.

5. Some cars still use leaf springs at the rear. Tired springs can often be restored by separating the leaves, sanding them clean and using strips of grease-impregnated cheesecloth between the leaves of the spring. A recent trick is using strips of thin teflon between the leaves.

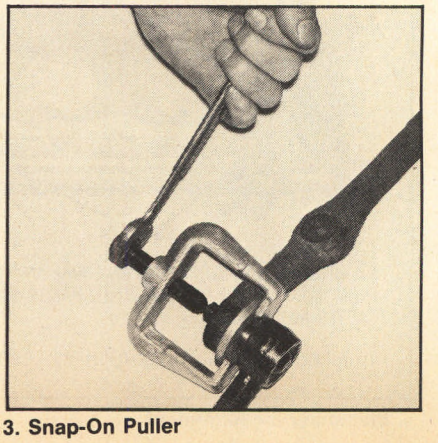
6. This schematic drawing shows the jack locations, maximum and minimum tolerances recommended by McQuay-Norris for most ball joint front ends.



1. Using "Pickle Fork"



2. Front-End Lube Points

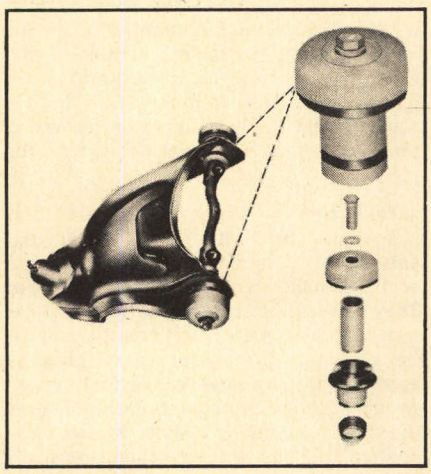


3. Snap-On Puller

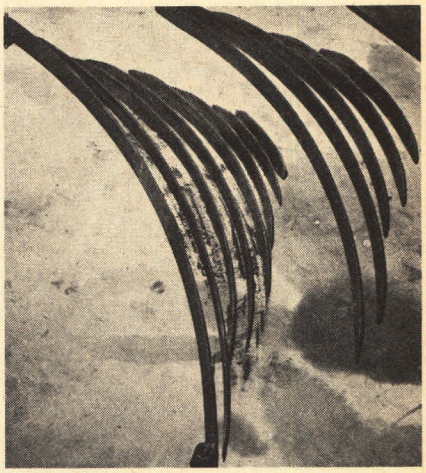
the opposite (right) side of the same dimensions as the pitman arm. The center link connects these two arms, and from these arms run short links to each front steering arm on the hub carriers. A variation of this has a drag link from the pitman arm to a point on a heavy center link that connects a pair of idler arms, one at each side, each of which connects to the wheels via short links, as in the second system just described.

What is of importance here are the links that run from the steering arms *at the wheels*. It makes little or no difference whether their inboard ends attach to a center idler arm, to the pitman and matching idler, or to a pair of idlers. These links have ends that are threaded right-hand on one end and left-handed on the other so that once the clamps are loosened, they can be turned or twisted. This either lengthens or shortens them, depending on which way they are twisted, which in turn increases or decreases the toe-in relative to the centerline of the car at the wheel that is involved.

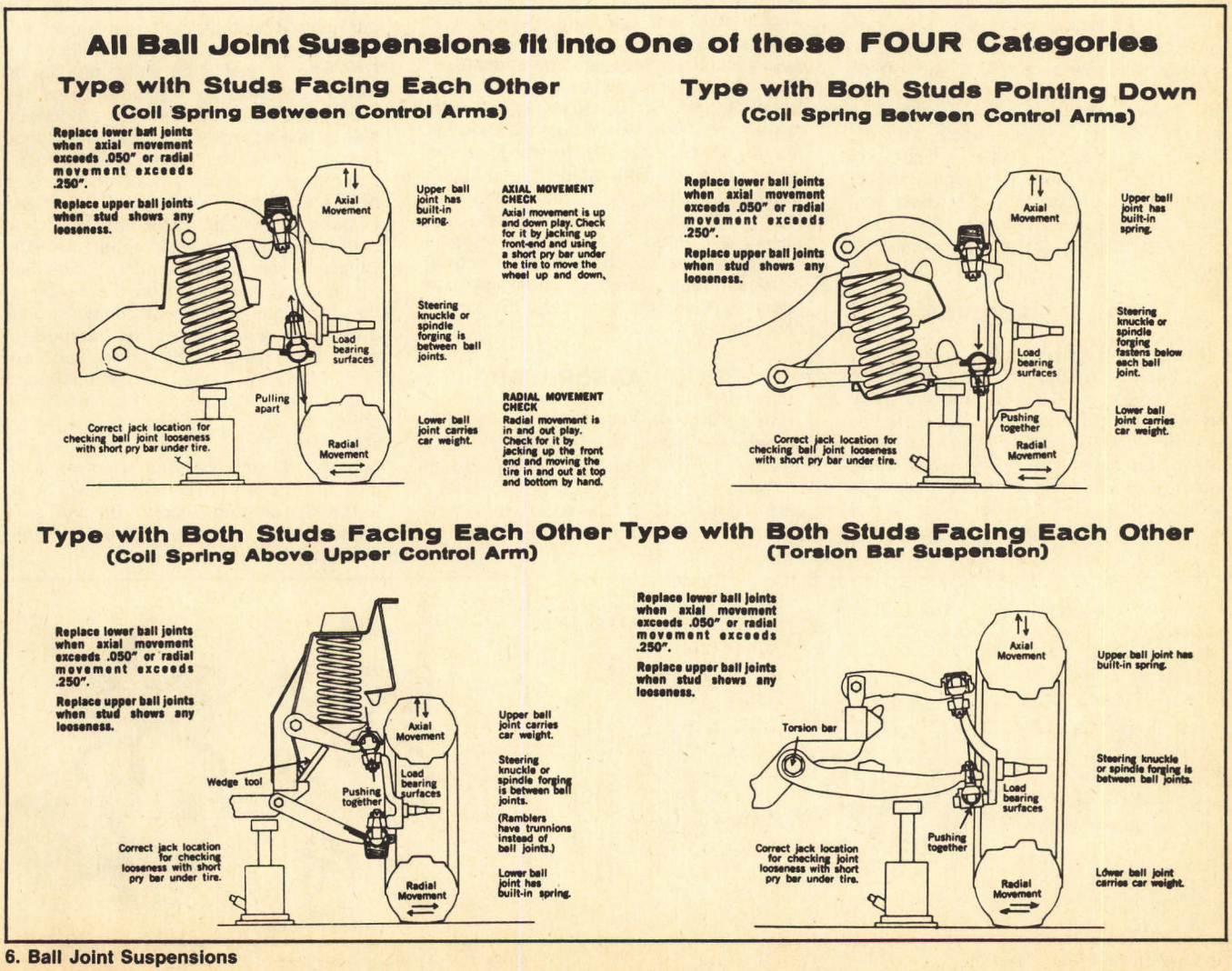
To find out how much or how little toe-in you have, raise the car and place axle stands under the lower A-arms as close to the wheels as possible. When you let the car down on the axle stands, the suspension must compress to its natural position, as if the wheels were on the ground, or as close to it as you can get. Next, use a piece of chalk to whiten the center of the tread all around each tire. Then hold a nail firmly against a solid support such as a concrete block, and "scribe" a line in the chalk by spinning the wheel. Now, with the wheels in the straight ahead position, all you have to do is measure how far the lines are apart at the front and rear of the tires. Suppose you got 50 ins. at the front and 50⅛ ins. at the back. You have ⅛-in. toe-in, because the scribed lines are ⅛-in. closer at the front. To be more accurate, the measurements between the lines should be taken halfway between the top and bottom of the tire. This is no problem in front, but when you move your tape measure in back, the frame gets in the way. What you need is a trammel bar. Get a piece of wood long enough to reach across both front tires, then make short extension pieces with a nail sticking out of each one so that the nail points can be put against each scribed line at the midpoint of the tire. By shifting the trammel bar from front to rear, you can easily see if the scribed lines are closer together at the front by the specified amount of toe-in. If they



4. JAMCO Bushings



5. Leaf Springs



6. Ball Joint Suspensions

aren't, shorten or lengthen the rods until they are.

Now check the position of the steering wheel. If it is centered, you're in business and you can tighten the clamps. If not, lengthen one rod and shorten the other exactly the same amount until the wheel is centered at the straight-ahead position, which is to say the "high spot" in the pitman arm travel.

As mentioned, camber and caster setting are really jobs for shops equipped with front-end racks and the necessary special tools—items that aren't likely to be found in gas stations or neighborhood garages. However, it is worth the time to mention how these values are set into various front ends. Perhaps the most common method is by means of stacks of shims of several standard thicknesses placed in some instances between the cross-shaft of the upper control arm and its frame support.

In other cases, these shims are placed between the pivot bracket of the lower arm and the frame or bracket in the lower underbody. In certain Ford products such as early Fairlanes, '64 and later Fords and Lincolns, the whole upper control arm assembly is moved in or out in slotted holes to which the cross-shaft is bolted. This last requires a special tool and should not be attempted without it. In all recent Chrysler products, the upper arm attaching bolts are equipped with eccentric washers. Turning both equally will adjust camber, and turning one or the other will affect caster. Some late Chevys and early Ramblers have a similar eccentric system applied to the *lower* control arms. Caster adjustments to Corvairs are made by lengthening or shortening the front end tie struts running from the suspension to the frame, changing the tension on the lower end of the spindle.

REAR SUSPENSION

Systems on American cars have pretty well been stabilized in terms of design since the early 1950's. In fact, the basic layout is nearly as old as the automobile in one form. Generally speaking, with only three exceptions, they break down into two types: Longitudinal leaf springs with live ("solid") axle, or coil springs and live axle with appropriate locators.

The exceptions are the Corvette Stingray, '61-'63 Pontiac Tempest, and the Corvair, which have various forms of independent rear suspension systems. The Stingray system uses a transverse leaf spring, a lower control arm with forward locator links, and axle half-shafts with universal joints at each end. Early Corvairs use diagonal control arms with swing axles universally jointed at the inner ends only. Late models use a coil spring modification on the Stingray theme with fully independent axles U-jointed at both inner and outer ends. The third exception, the Pontiac system, is quite similar to that of the early Corvair. It was discontinued primarily due to the inability of the transaxle, which went with it, to take the torque of the various engines with which it came. Due to this transmission frailty, comparatively few of these cars are in current service on the road.

Taking the most common type of rear suspension first—the longitudinal leaf and live axle—prime points of wear, other than inside the axle itself, are few. They are almost all due to neglect, extended hard usage, or impact damage. So simple is the system that, properly assembled, there is very little that can go wrong in terms of alignment. In essence, the basic layout consists of two leaf springs, usually stacks of progressively shorter leaves and a master leaf (occasionally one single broad leaf), solidly anchored toward the front of the car at the frame rail and fastened via a movable shackle at the rear. The shackle allows longitudinal movement of the spring as it bends, but is rigid to sideways movement. The axle housing rests on blocks placed slightly forward of the center of each spring, each end being fastened solidly to, and above, the spring. In case of a multiple spring, the leaves are held together by what is known as a center bolt but which actually runs through directly under the axle housing. Additional clips keep the longer secondary leaves in line.

SHOCK ABSORBERS

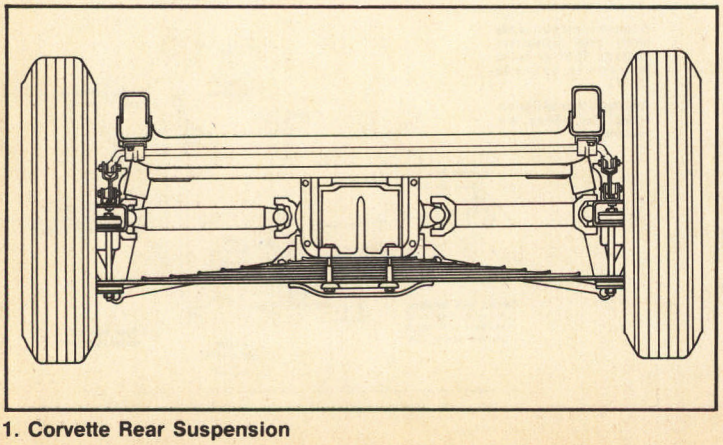
On earlier cars, lever action shock absorbers are bolted to the frame rail and attached by a link to the axle housing or its mounting pad. On virtually all modern cars a direct-acting telescope-type shock absorber runs between the mounting pad and either a bracket on the frame rail or the rear crossmember.

The main points of wear are generally the shock absorbers, the shackles and their bushings and pins, the front bushing and pin, and finally the leaves themselves on a car that has been neglected or overloaded so as either to bend the spring permanently, wear the ends of the leaves, or break one or more leaves.

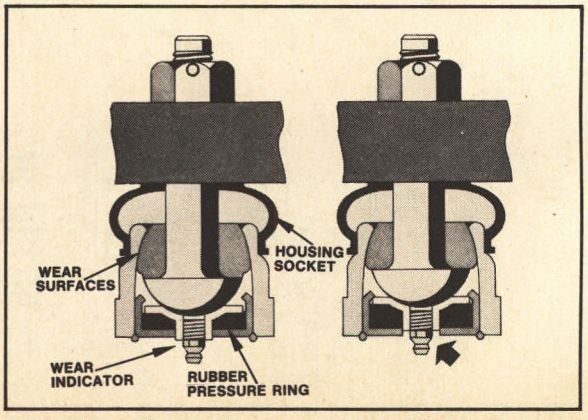
Shock absorber wear is easy to detect and easy to fix in case of the tubular type. Press down vigorously on the corner of the car over the particular shock and then release quickly. If the car eases up to just above normal height and then returns gently to normal, the shock is working. If it continues to oscillate you have found a bad one and should replace it. Tubular shock absorbers are not refillable or repairable in service and must be replaced. To replace a shock absorber on the type of suspension under discussion is simply a matter of jacking the car up at the axle and unbolting the shock at the bottom stud or hanger and at the top and then removing it. Replacement is just as simple. Put the new unit in just as the old one was removed, being careful to use the new rubber bushings where noted.

REAR AXLE ALIGNMENT

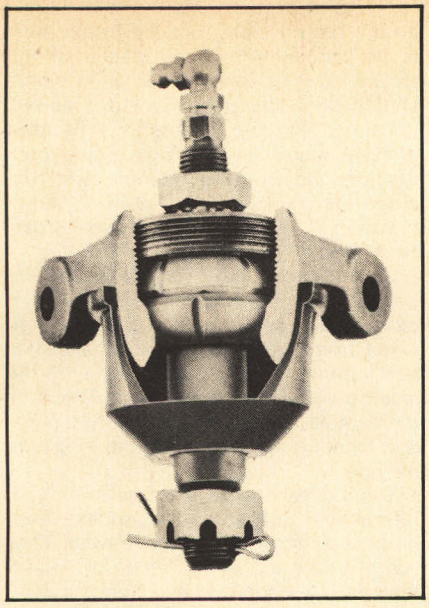
Misalignment caused by axle displacement is easily detected by running the car over a wet patch of pavement followed by a dry section. The tracks of the rear wheels should be either directly on top or equidistantly inside those of the front wheels. If the track is off to one side or the other, or if a properly aligned front end must be turned slightly to go straight, the rear axle is off to one side or one end of it is misaligned respectively. Jack up the car and look at the lower spring clip plate directly under the axle. Check to see that the spring center bolt (or tie bolt) is in place in the center of the clip plate. If it is not, loosen the U-bolts and, with the spring supported, move the axle until the center bolt centers in the hole in the clip and the spring block. If the clips and bolts are centered, check to see if the axle is displaced sideways. This can be checked any number of ways but the simplest is to measure the distance from the spring to a clearly definable point on the axle housing on each side. If the two mea-



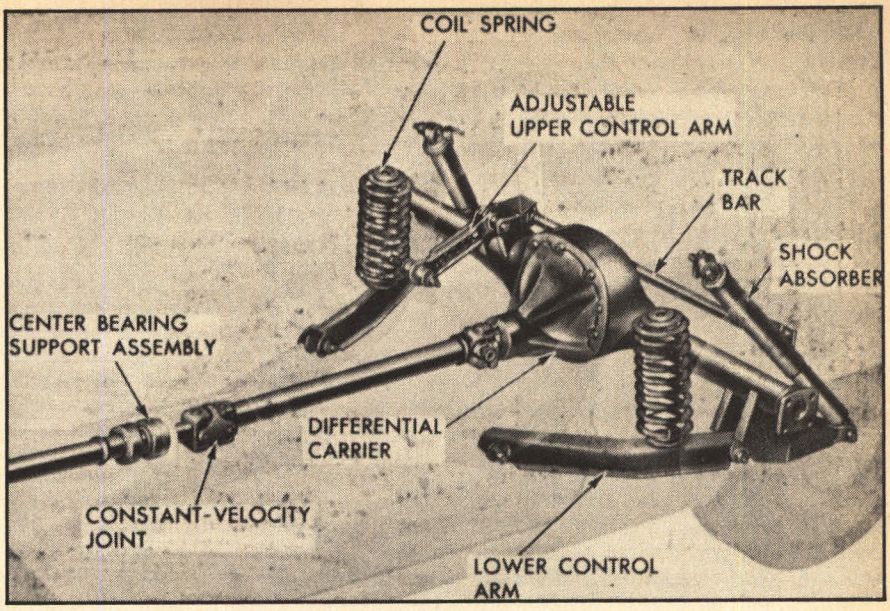
1. Corvette Rear Suspension



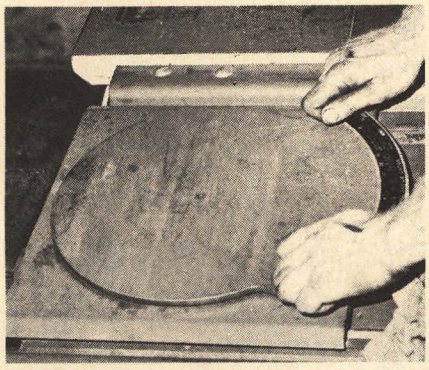
2. Ball Joint Wear Indicator



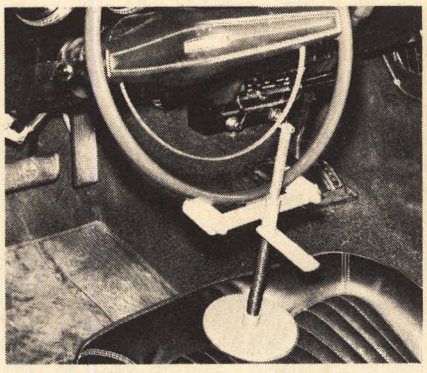
3. Moog Ball Joints



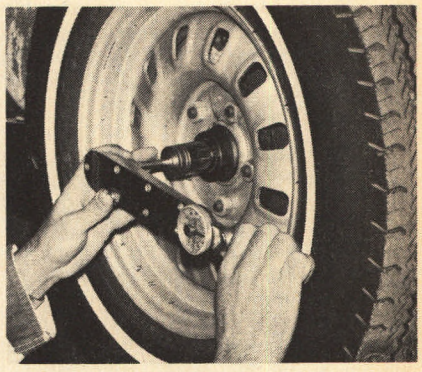
4. Typical Rear Suspension



5. Locking Turntables



6. Steering Wheel Clamp



7. Torquing Wheel Bearings

1. The '63 and later Corvette with independent rear suspension uses a transverse leaf spring reminiscent of the early (pre '49) Fords.

2. Oldsmobile ball joints are designed with a built-in wear indicator for 1973 models. As the joint wears in the housing socket, a rubber pressure ring expands and causes the wear indicator to recede into the housing. Replacement should be made when wear indicator has receded .050-in.

3. Some replacement ball joints, like this Moog unit, are adjustable to compensate for wear. If your old ball joint was held in by rivets, the replacement kit will have special bolts to replace the rivets.

4. Coil-sprung rear suspensions use upper and lower control arms to keep the rear end located and aligned. A track or sway bar is sometimes used.

5. When you pull into a front-end shop for an alignment, the first step the mechanic will take is to lock the turntables in place to protect the swivel bearings while you drive your car onto the rack.

6. The steering wheel (and often the brake pedal) is locked with a clamp like this to keep wheels from moving.

7. One of the first steps in a good alignment job should be adjustment of the front wheel bearings. Use of a torque wrench is not common, but it's the most accurate way to do the job.

surements are not equal, loosen the U-bolts on either end and bump the axle back into place—then tighten up the bolts.

To service shackles, bushing pins, and the spring itself, it is best to remove the spring entirely from the car. It is, strictly speaking, a relatively simple operation but one that requires care. A spring under tension is like a bomb with a lit fuse. If let loose under these conditions it can do a lot of damage, primarily to you.

LEAF SPRING SERVICE

To remove a leaf spring, raise the car and support it with axle stands under the frame, so that the axle hangs free. Then put your jack under the axle and raise it just enough to take the weight off the shackles. If you get the axle positioned just right, you should be able to unbolt the shackle studs and slide the shackles out easily. On some cars the shocks will not extend far enough to let the axle drop to where you want it. In other words, the shocks hold the axle up so that the springs are still under compression. It's easy to disconnect the shocks so you can let the axle down, but be careful of the flexible brake line. With the shocks disconnected you can easily let the axle down far enough to stretch the brake line, pull fittings loose, and generally ruin your brake system. If you have to, disconnect the line, and plan on bleeding the brakes after you connect it up again.

With the shackles off, it's easy to take the nuts off the U-bolts and drag the spring out from under the car. Leave the axle right where it is, and you will find it a lot easier to get the spring back in.

Using a C-clamp or vise, hold the spring stack together near the center bolt and loosen the bolt, then slowly loosen the clamp or vise until the leaves are loose. Now you can check for broken or cracked leaves, worn anti-squeak inserts, and worn or distorted clips, shackle bolts, and bushings and replace where necessary. To reinstall, simply reverse the above procedure.

While on the subject of leaf springs, it might be wise to bring up the pre-1949 Ford products since there are still a goodly number of these in service either in standard or modified form—i.e., hot rods. In case you hadn't noticed, the pre-1949 Ford is suspended by means of one inverted semi-elliptic transverse spring at either end. The upper part of the spring bears against the front or rear crossmember and the ends ride on shackles at the outer ends of each axle. You don't just jack this one up at the spring and the frame, and lower the jack. If you try that, the doctor will be repairing you, instead of you repairing the car.

The sanitary way to remove a cross-spring is by means of a spring spreader. On these springs, the eyes at the ends

are rolled downward. A spring spreader is a device that is half thick-walled tube and half threader bar. A large nut rides on the threaded bar which slides into the tube. The ends of each half are beveled like blunt chisels. The nut is run down the bar to the tube, forcing the two halves apart. After inserting the chisel points into the rolled spring eyes, turn the nut which bears on the tube portion and forces the spring ends apart; this relieves the tension on the shackles which can then be removed safely. A less sanitary but effective way is to take a piece of heavy-wall pipe or tubing just a fraction of an inch longer than the distance between the spring eyes, and flatten the ends with the aid of a torch and hammer. By increasing the normal load on the spring as in a bump condition, you can force this bar into the eyes. When the load is removed the bar contains the tension. This is good only if all you want to do is get at the shackle bushings or remove the axle. Once you get out of the car with this system, the spring and bar had best stay together until the load has been replaced.

And don't do the job the way we saw it done by one young man who is alive today only because he's very lucky. He had the spring spreader in position and was trying to hammer the shackles off the end of the shackle studs without any support for the car itself. You must support the car frame firmly on stands. Then jack up the rear end to a point just before the jack starts to lift the frame of the car off the stands. Then you should put the spring spreader into position and put wooden blocks under the tires to support the rear end before removing the shackles. Any work under a car can be dangerous if you don't know what you're doing. When you're not sure, get some confident advice from somebody who has done the job before.

COIL SPRING REAR ENDS

Coil spring rear suspension systems have been used on Buicks literally since the year dot. Variations on this system were adopted by the General Motors compacts in 1961 for the small Buick, Olds, and Pontiac; the latter used an independent system for three years and then fell back into line with the others and used a live axle with locators.

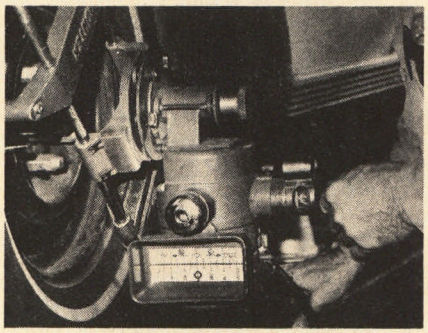
The larger Buicks and the small Buick-Olds-Pontiac compacts differ significantly in detail in terms of the kind of locators used. Where the leaf spring rear suspension is self-locating due to the rigid fore-and-aft, side-to-side mounting action of the springs, coil springs by their very nature can be moved in any direction. Therefore a coil-mounted suspension system must be rigidly held in any direction but that in which it is supposed to move—i.e., up and down.

In the original Buick system, fore-and-aft location was by means of a torque tube, a large-diameter tube that surrounded the driveshaft and was solidly mounted to the differential housing. At the front it was attached by a large, hollow ball joint at the transmission; the ball housed the U-joint at that point. Side-to-side location was by a bar—attached to the axle housing at the right end and running to the frame on the left side—known variously as a track bar, Panhard rod, and sway bar. This bar is still used on the large Buicks, but the torque tube is no longer with us. In place of the torque tube for longitudinal or fore-and-aft location, two diagonal lower control arms that also carry the springs are used in conjunction with a single upper control arm, adjustable for length and running from just to the right of the differential case to one of the transverse crossmembers.

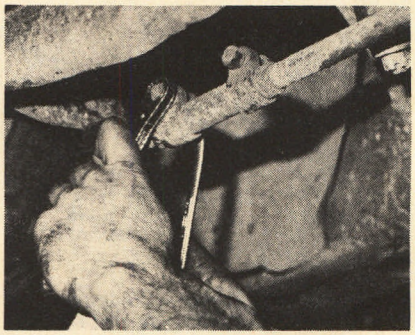
On the small B-O-P cars (except Tempest '61-'63) the action is somewhat simplified. Two larger control arms are pivoted from the frame ahead of the axle and connect to the lower side of the axle housing at the outer ends. These do the twofold duty of preventing "wrap-up" and locating the axle along the longitudinal line.

The upper control arms provide both lateral and additional longitudinal support, and further control axle-twist. They run from the top of each side of the differential case forward and outward diagonally to the top of the rear crossmember. On both the large Buick and the B-O-P cars sealed, tubular, shock absorbers run from the outside rear of the axle housing diagonally inboard and forward to attaching points on the frame.

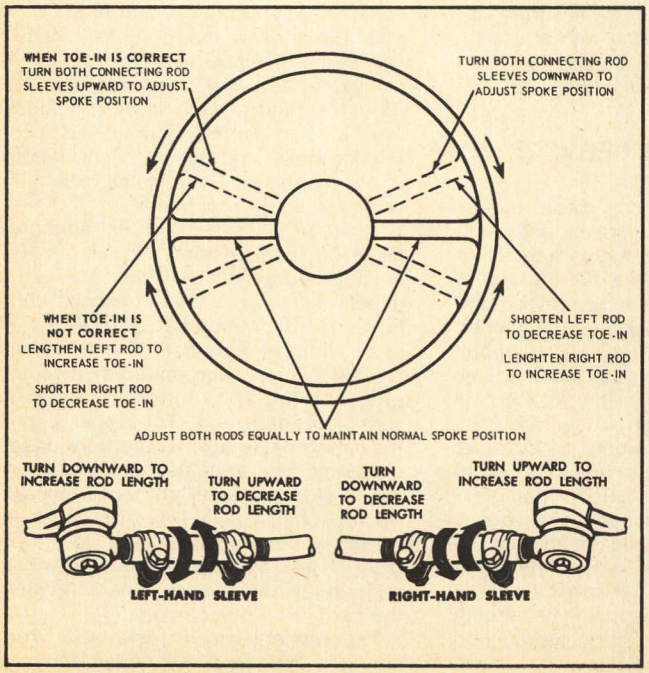
In no case do the service manuals give alignment or adjustment instructions on these rear ends. With all the locators properly in place the rear end is in align-



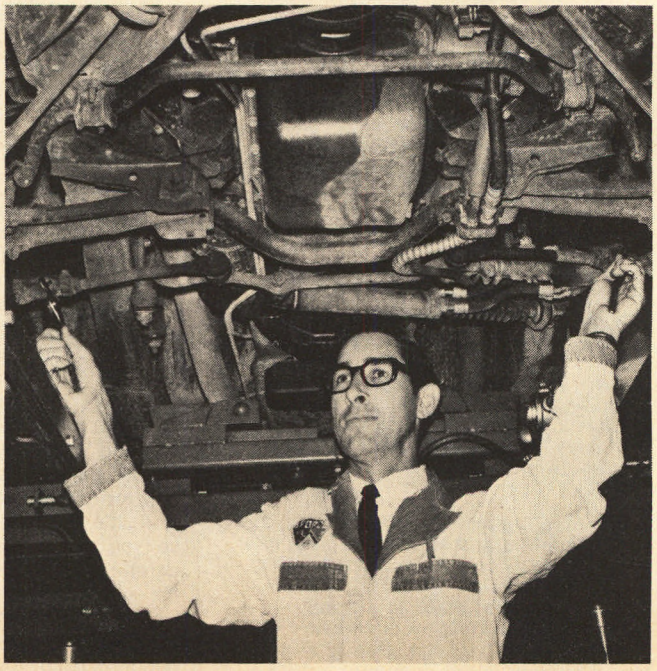
1. Hunter Alignment Arm



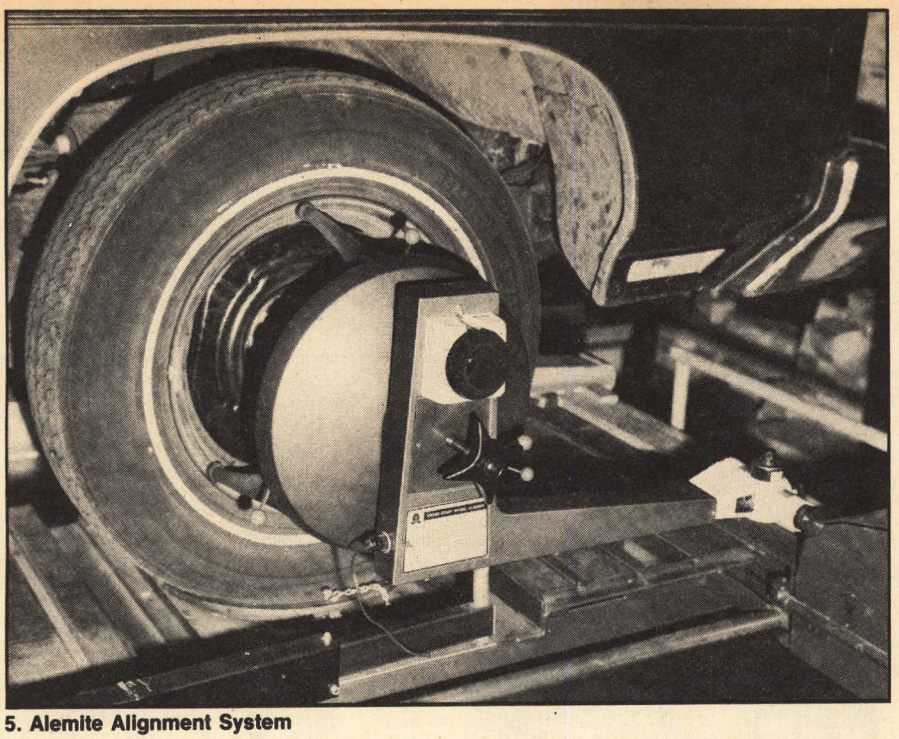
2. Loosening Tie Rod Clamp



3. Centering Steering Wheel



4. Making Toe Adjustments



5. Alemite Alignment System

1. There are several types and makes of alignment equipment, but a good job depends mainly on the way it's done rather than the equipment type. In most systems, an alignment arm is attached to the spindle. This is the alignment arm used in Hunter system.

2. Clamps on the tie-rods must be loosened to make toe adjustments. If you live in a very wet climate or if your front end hasn't been aligned in a long time, you may have to soak the tie-rod threads in penetrating oil for a few days and then go back to the shop for alignment.

3. When a car has two tie-rods, you can adjust either one, but this will also change your steering wheel's position. Check this guide for the way to correct placement of wheel.

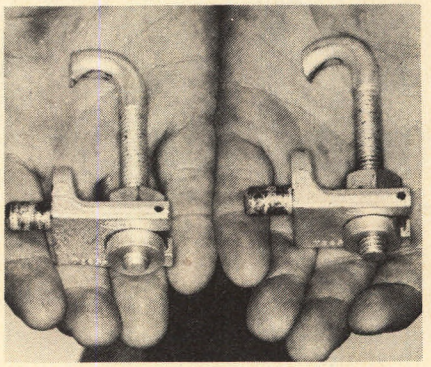
4. Some alignment systems have wires running from the alignment arms on the wheels to a control panel with a monitor that shows the wheel alignment. This way is quicker and allows mechanic (who is watching monitor) to turn both tie-rods at once so as not to affect steering wheel position.

5. The Stewart-Warner Alemite people have come up with a new alignment system that utilizes line-of-sight, with cross-hair sights in the arms that attach to the car's wheels.

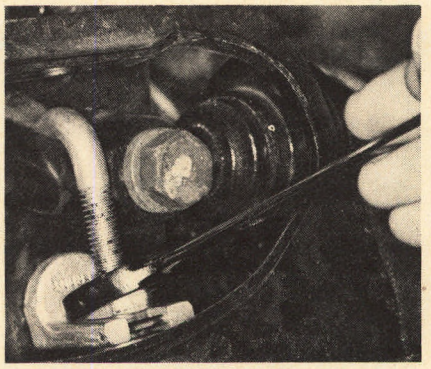
6. Large Ford products present a special problem when making camber changes. These tools make the task a great deal easier.

7. The tools are placed over the upper control arm shaft so that when the bolts that hold shaft in position are loosened, the control arm shaft will not slide around.

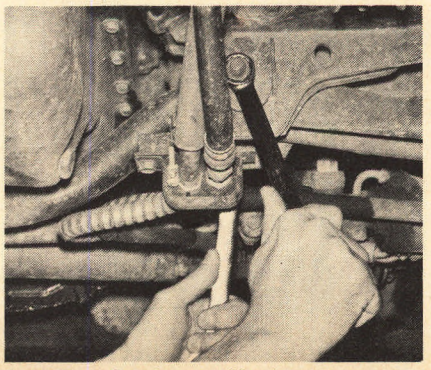
8. If it's necessary to change the camber on this Mustang, we go to a cam at the inner end of the lower control arm. Holding one side with a wrench while turning the other will make the camber change.



6. Special Ford Tools



7. Adjusting Ford Front End



8. Setting Camber on Mustang

ment and that's that. If it isn't in alignment, then one or more of these components has been bent or damaged and must be replaced.

On the B-O-P cars, virtually any or all of the various locators can be removed and replaced without removing the axle. All that need be done is to raise the frame to the point where the wheels are off the ground, then raise the axle housing until all strain is off either upper locator, at which point the various fastenings can be undone and the damaged unit removed. The lower locators require that the springs be removed, but here again the job is relatively easy if done with care. Raise and support the chassis so that the wheels are in the air, then raise the axle. Provide slack in the parking brake cable so that it will not be damaged and disconnect the shock absorbers at their lower ends. Remove the bolt and clamp that holds each spring at the lower end and then lower the axle. In replacing the springs, position the springs so that the larger end, which is also ground flat, is at the top of the upper spring seat. Raise the axle and connect the spring to it with the clamp and bolt. If you have found spring sag, there are several remedies: 1) Purchase new springs rated for your model; 2) There are shims available at B-O-P dealers; and 3) If you are looking for stiffer handling or plan on carrying heavy loads, there are special 200- and 500-lb. overload springs available for your car.

A word on coil springs and their removal in general is not out of place at this point. As with any kind of spring under tension, treat them as though they were live grenades. As outlined above, coil spring rear ends do not require any special tools or procedures, just care in assembly and disassembly so that they don't leap out under partial load when you're halfway into the job. Front end springs are a different breed of cat. First, in virtually all instances, the shock absorber rides inside the spring. Removing this leaves access from top to bottom through holes in either end or both, and while some manuals don't specifically recommend using special tools, a simple screw-type coil spring compressor is an especially useful object to have and to use both for simplicity and your own peace of mind. On cars with springs between the control arms it isn't necessary but is handy; on cars with the springs above the upper control arm it is a necessity. Among these are all the Ford products that use the system and certain of the American Motors products.

LATE CORVAIR OR CORVETTE

There are two types of rear end suspensions we haven't touched on as yet—the fully independent units of the '64 and later Corvair, and the Stingray Corvettes. Both are referred to as "4-link" systems using longitudinal torque arms, transverse strut rods and the axle half-shafts themselves. The torque arms also act as hub carriers. The major difference between these two is that the Corvette uses a single transverse leaf spring-stack mounted under the rear of the stationary center section, and the Corvair uses

coils mounted between the frame and the hub carrier ends of the torque arms.

These rear ends are hardly self-aligning, and both have definite camber and toe-in requirements. In no case is this a home garage or backyard type of job. About the only job that should be done on these cars outside of a properly equipped shop, as far as the rear end goes, is shock absorber replacement, which is done as on any other car. Springs also may be removed for renewal where there is a hydraulic floor jack and jack stand available.

In the case of the Corvette, the procedure is as follows: Raise the rear of the car and support it on jack stands placed just forward of the torque arm pivot points. Place the floor jack underneath the outer end of the spring at the link bolt. (Note: the Corvette spring, unlike the early Ford, does *not* have spring eyes. A link bolt through the torque arm holds it.) Raise the jack until the spring is nearly flat. Now wrap a chain of at least 1/4 or 5/16 size around the spring and the suspension crossmember above it, and secure it with a safe grab hook. *Do not use cable, rope or anything else for this purpose*. Cinch down a C-clamp inboard of the chain to keep it from slipping. Now lower the jack and remove the link bolt with the chain holding the spring. Raise the jack again and remove the chain and then slowly let off the jack and allow the spring to release fully. Repeat this process on the other end, and when both are released, remove the four bolts and spring pad under the differential case, then slide the spring out sideways. *Do not take any shortcuts!*

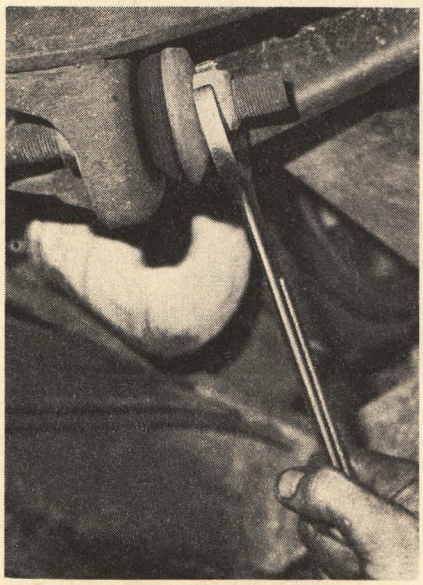
On the Corvair, things are a bit simpler. Raise the rear of the car and place on jack stands as with the Corvette, the stands placed at the pads forward of the torque arms. Place the jack under the torque arm at the hub carrier and raise it up to curb height. Release the rear strut rod at its differential carrier end and release the shock absorber at the bottom end where it attaches to the torque arm. Now slowly lower the jack, allowing the spring to extend to its full length. Remove the spring, spring retainer, and cushion from the frame. To replace it, reverse the above procedure, making sure that the spring is properly indexed into the cushion and seat.

ADJUSTABLE SHOCKS

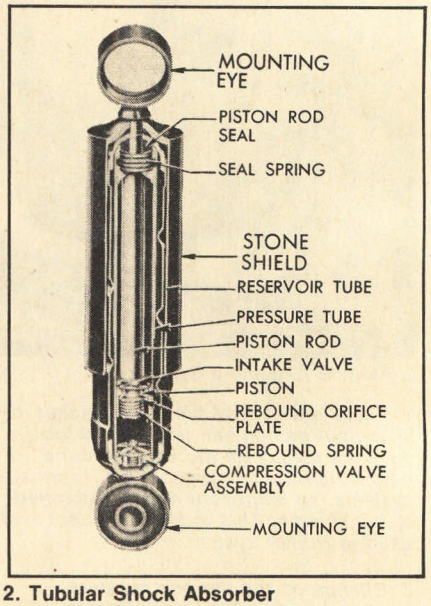
There are three makes of shocks, or rather types within makes, that can be adjusted, rebuilt, or both. These are all, as far as the American market is concerned, replacement items.

Foremost among these is the justly famous Koni, made in Holland but marketed wordwide. Perhaps its first claim to fame is total, uncompromising quality. Every unit is matched internally to exact tolerances and all the valving and sealing is metallic; there is no plastic, leather or rubber on the piston whatever. Quality aside, what made it really well-known is the fact that it can be infinitely adjusted from just the soft side of firm to nearly rock hard when new. Except for competition, very few are set hard to begin with. Tailored individually for the car involved in terms of control ratio, they are generally installed in their softer setting or just on the firm side and then as time goes on, they can be gradually adjusted to take up for wear or other conditions. Combined with the quality control, this feature makes them good for the lifetime of the car, which more than justifies their initially higher cost. Setting is accomplished on the Koni by disconnecting it and collapsing the shock all the way, then turning the lower half gently until a slight click is felt. Turning one way hardens it and the other way softens it. The adjustment is done inside by a nut that progressively shuts off orifices in the central valving. Another point with the Koni is that it can be rebuilt and even tailored in action by any of the several distribution centers around the country.

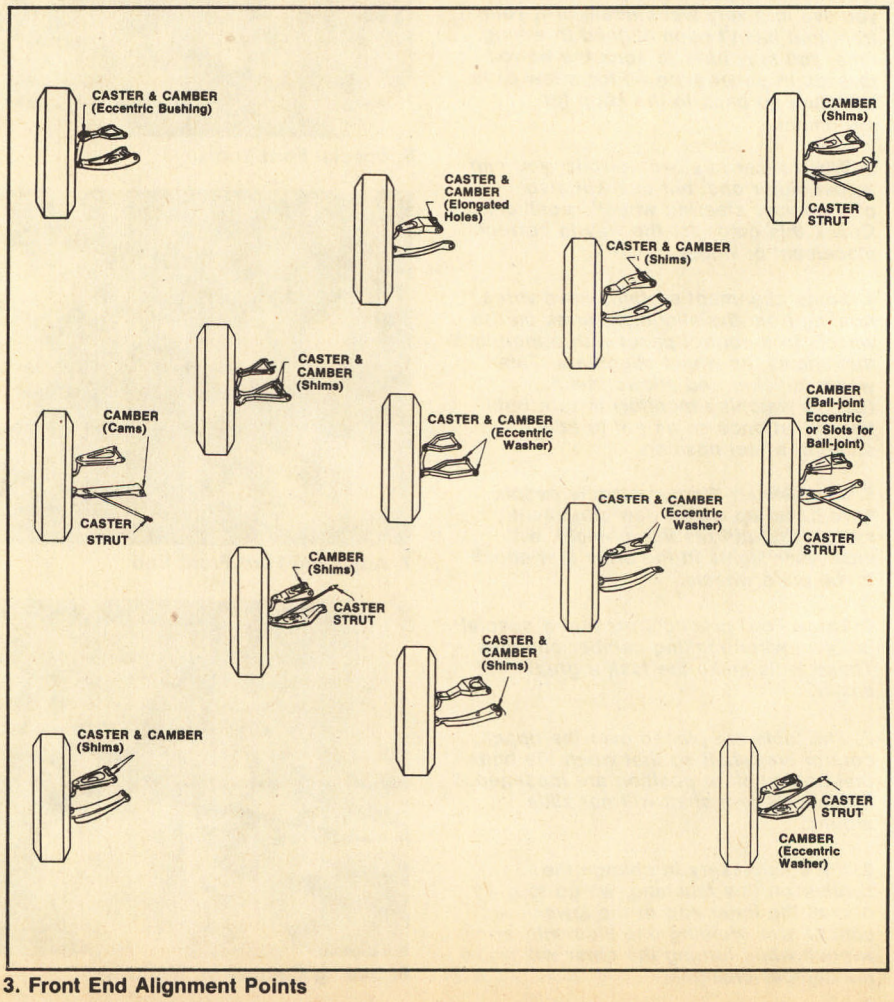
Another of the adjustables is the Armstrong which can be had in both lever



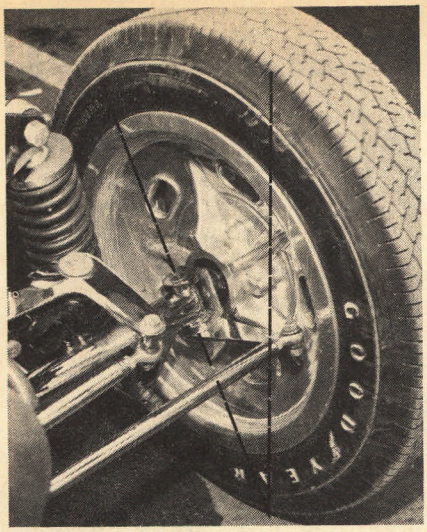
1. Adjusting Strut for Caster



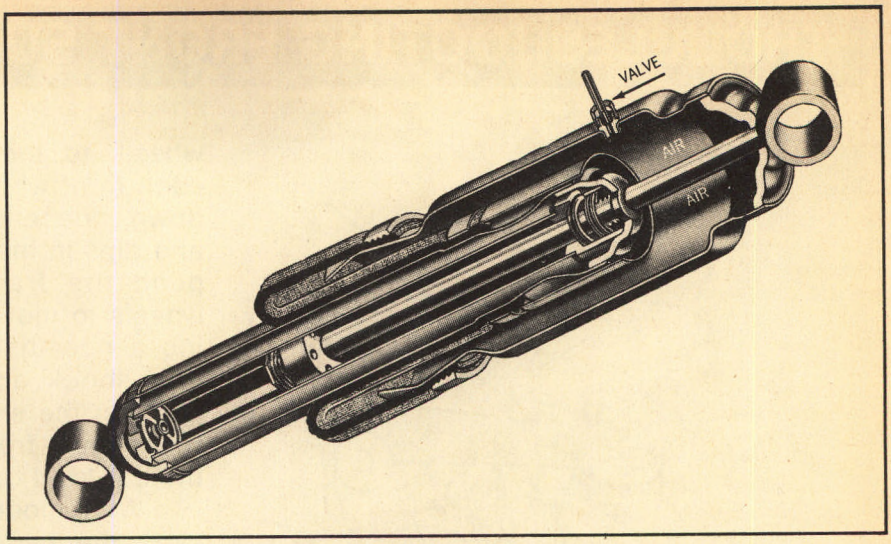
2. Tubular Shock Absorber



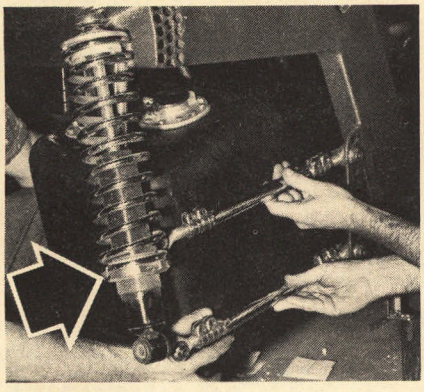
3. Front End Alignment Points



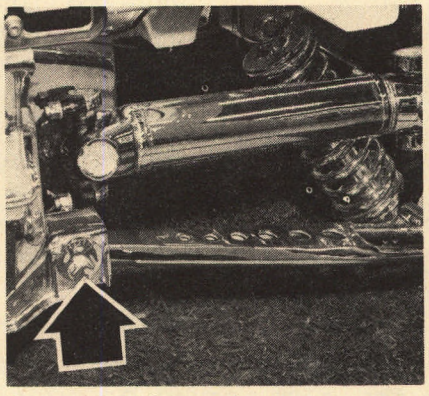
4. Positive Caster on Race Car



5. Air Shock



6. Coil/Shock



7. Street Rod Suspension

1. On cars with strut suspension, like this Mustang, the caster can be changed by lengthening or shortening the strut. Loosening one nut and then tightening the other will change the length of the strut.

2. The condition of your shocks has an effect on your handling. There's no sense in spending money for an alignment job if the shocks are shot. Most tubular shocks are of the design shown. Oil, moving through orifices, provides the dampening action.

3. This chart shows the various types of front ends and methods of alignment used on late model cars.

4. Drag racing cars are set up with several times the positive caster of a normal passenger car. By almost "forcing" the front wheels to go in a straight line, this makes the car handle better in straightline racing.

5. Air shocks are popular accessories today for vehicles that carry heavy loads, like campers and trucks. This cutaway shows how pumped-in air fills "bag" around top of shock, to either raise rear of car or provide extra load-carrying capacity.

6. Combination coil springs/shocks are used in many types of racing and street machines. This type features an adjustment (arrow) for changing the amount of spring tension.

7. Very popular with the street rod set are the independent rear ends like the Jaguar and Corvette. Note cam bolt used to set rear wheel alignment.

and tubular form. In the latter form, combined with an integral coil spring, it is used by most of the finest racing cars in the world. Its great advantage is that it can be adjusted from the outside while mounted on the car, a feature also available on a few models of Koni. There are two forms. One adjusts through 10 positions by means of a knob on the side of the shock tube or in the case of a shock meant to ride inside a front spring, by means of a slotted head in the same place that can be turned with a screwdriver. Another form adjusts from the dash through four positions by means of a remote control unit within the car.

A third adjustable is the Gabriel Adjust-O-Matic which is set, like the Koni, by detaching and collapsing the shock to engage a pawl inside the unit. The Gabriel, however, does not have the infinite adjustment of the Dutch shock but has three positions: soft, medium, and hard. Again the prime purpose is to take up for wear and age, but it can be used to make the car suitable for different road surfaces or high speeds. It is much more widely available than the other two and less expensive, which offsets its lesser range of capability.

There is also a so-called adjustable type of shock, the air-filled unit made by Delco for GM cars. This unit is optional as an overload item on most GM cars, especially station wagons and the El Camino pickup. Adjustment is by bleeding air off for softer settings and adding it from a filling station hose for harder settings. However, this is not a true shock adjustment, but rather a helper spring, since the air does nothing to dampen the action, operating only on bumps.

CHASSIS MODIFICATIONS

The best advice we can give on chassis modifications is that if you don't really know what the modification is for and what it will actually do other than look different—then DON'T.

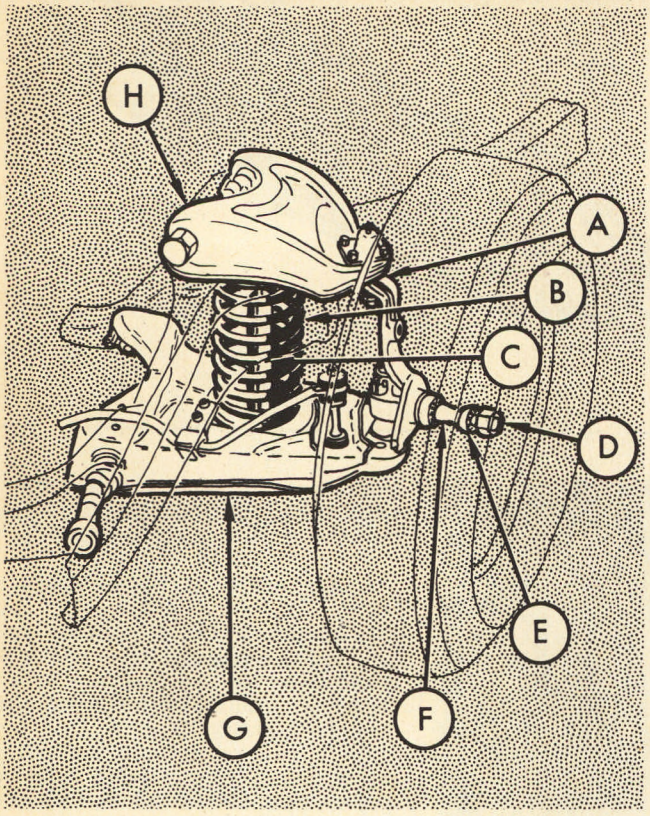
The chassis setting as it comes from the factory is a compromise meant to give the best ride with the best handling and ease of operation for everyday driving. A little of the ideal is given up in each area to produce a good balance. However, modifications can be and are made to produce a given effect for a given use—but there will always be a sacrifice in one or another area to produce the effect most desired.

A car modified for straight-line acceleration with soft shocks on the front, hard ones on the rear and the suspension raised to provide strong weight transfer to the rear wheels for traction will handle poorly on the street and will be unmanageable in highway cruising.

Conversely, a car set up to handle on a road course for sedan racing with its lowered suspension, stiff shocks front and rear set to a 50-50 or 60-40 ratio, and quick steering, will entail sacrifices in a harsh ride and stiff control at low speeds. Some high-performance factory cars are balanced in this direction for better road handling, however, and if you don't mind a slightly harsher ride they can feel very safe indeed. Low driveways and rutted country roads can be a pain, though.

In other words, don't depart from the factory chassis specs unless you know exactly what you want and can get the advice of an expert on what the effect of any given change will be. This even applies to the widespread practice of switching tires and wheels around either to get the wide look or for more traction. Done right, it's fine, but done without regard to the basic chassis geometry it can result in some funny steering conditions at least and very possibly ruined wheel bearings and even broken spindles. If you want to modify, do it—please do it right.

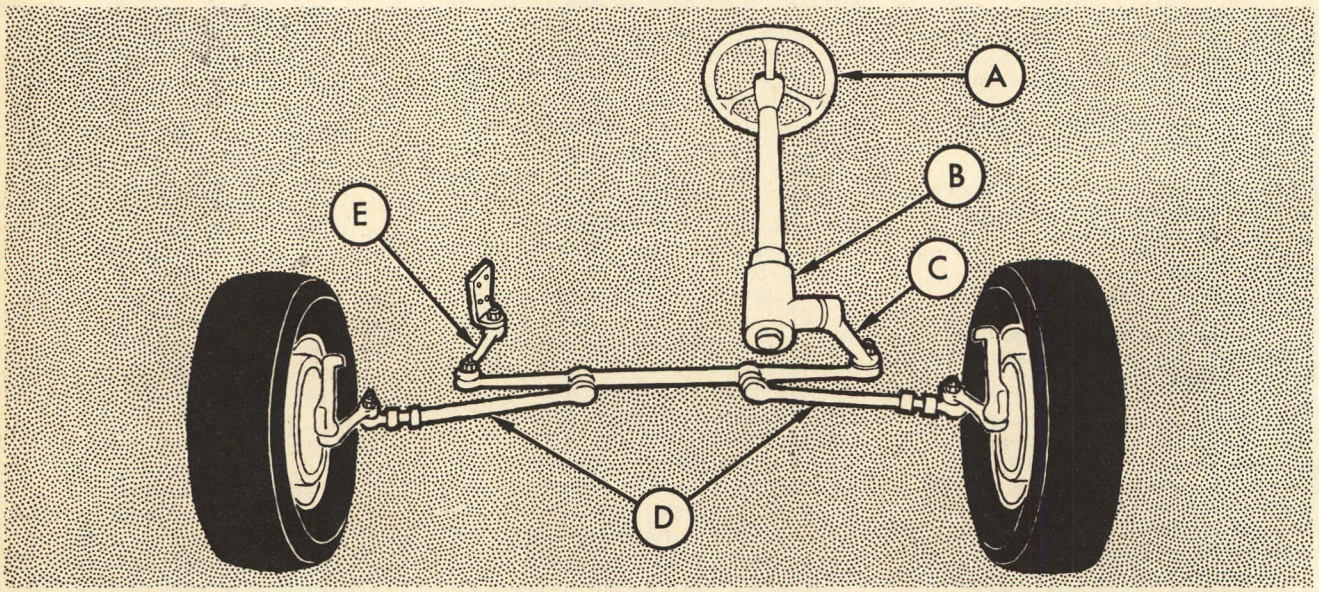
TROUBLESHOOTING FRONT SUSPENSION



The front suspension attaches the front wheels to the frame of the car. It permits each front wheel to turn and to move up and down independently when going over bumps and dips in the road surface. Springs (B) suspend the frame and body and allow the wheels to move up and down while maintaining a ride that's as nearly level as possible. The shock absorbers (C) are designed to dampen the shock of a bump and isolate the passengers from impact. They also help keep the car level on turns.

With modern independent front suspension, the car's weight is supported by ball joints (A). These work like knee joints, allowing the suspension to flex and the front wheels to pivot. The portion on which the wheel actually rides is known as the spindle (F). The wheel is supported by bearings (E) which go over the spindle, and the wheel is retained by a large nut (D). The pivoting portions of the suspension are called control arms. These are attached to the frame and the ball joints. There is an upper control arm (H) and a lower control arm (G).

NOTE: THERE ARE MANY DIFFERENT FORMS OF SUSPENSION USED ON AUTOMOBILES. SOME DO NOT HAVE THESE KINDS OF CONTROLS; OTHERS MAY HAVE ONLY ONE CONTROL ARM. BE SURE TO EXAMINE YOUR SUSPENSION CAREFULLY OR CHECK THE SHOP MANUAL FOR FURTHER INFORMATION. ALSO SEE PETERSEN'S BASIC CHASSIS, BRAKES AND SUSPENSION.



The steering system, which is connected to the front suspension, is made up of several parts. The steering wheel (A) is attached to a shaft, which runs to a gearbox called the steering box (B). The steering box transforms the movement of the steering wheel into car motion by means of the pitman arm (C). The pitman arm is attached to the spindles of both wheels by a series of rods called tie rods (D). Extra support for the steering linkage may be added by an idler arm (E).

For our purposes, it is enough to say that the wheels are controlled simultaneously by the steering mechanism and that both move in the same direction. Actually, the front wheels move in a complicated path that requires considerable automotive engineering experience just to understand, but it is not necessary to know all this to troubleshoot the suspension and steering.

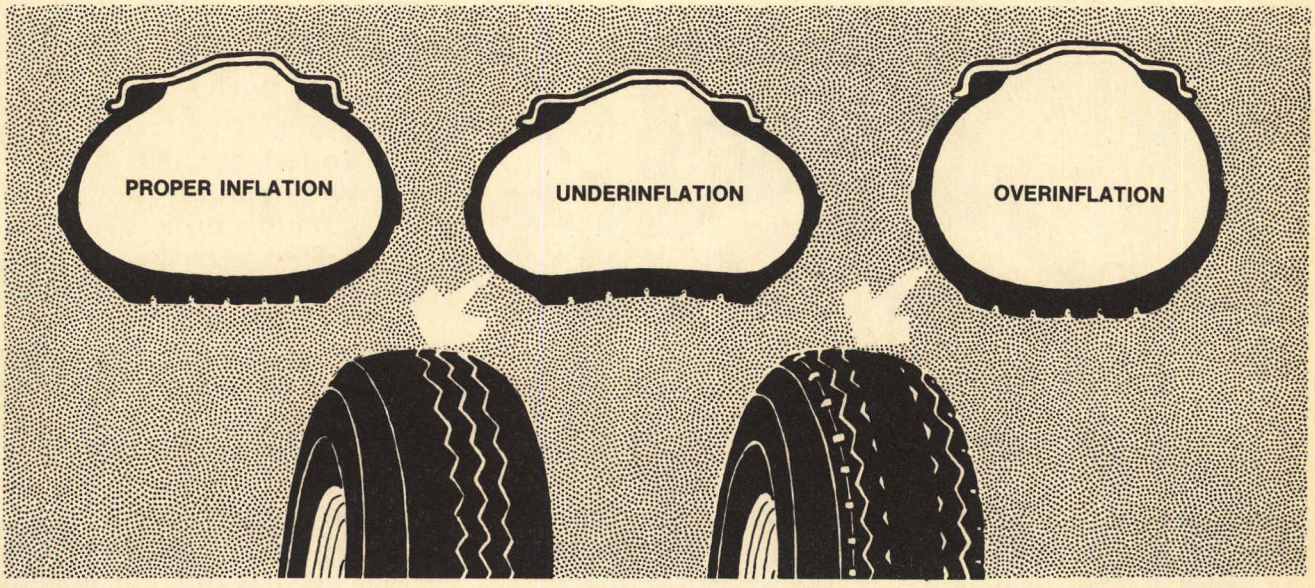
The most obvious indicator of a front suspension problem is the way the car handles. Such things as poor directional stability or hard steering are easy to recognize. A quick check for front suspension problems is best accomplished by test driving the car. Select a place where you can maneuver the auto without risk of an accident. A large, empty parking lot is a better choice than the highway unless you have access to a section of lightly-traveled road.

For the test, drive the car at a speed of about 20 mph. Loosen your grip on the steering wheel so that the car is not being directed by your actions.

WARNING: IF YOU CAN SEE THE STEERING BOX MOVE WHEN THE STEERING WHEEL IS TURNED, THE BOLTS HOLDING THE STEERING BOX TO THE FRAME ARE LOOSE. THIS IS A COMMON PROBLEM ON SOME CARS AND CAN BE VERY DANGEROUS.

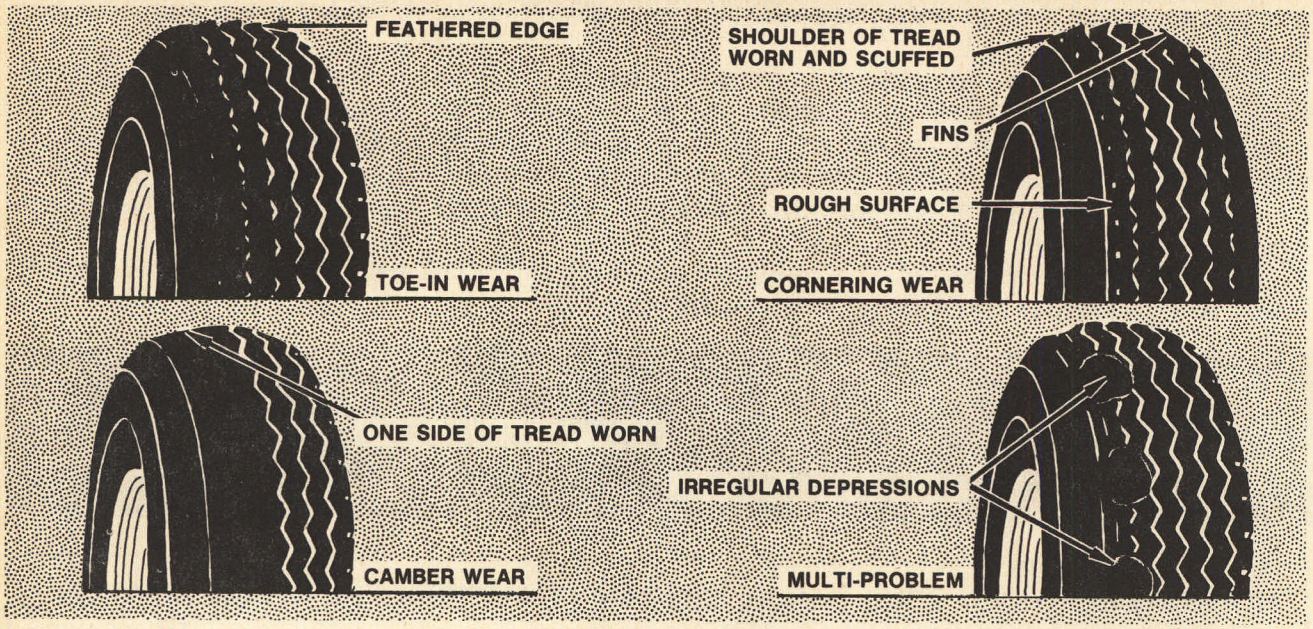
NOTE: DO NOT HOLD YOUR HANDS TOO FAR AWAY FROM THE STEERING WHEEL; YOU MAY NEED TO GRAB IT QUICKLY.

The car should maintain a straight course. This test is best performed where the road surface is perfectly flat. Most highways have a slight hump or "crown" in the center for water drainage. This crown will cause the car to steer to the low or outer side. Carefully notice if any vibration or chattering is fed back to the steering wheel by the suspension. A constant chatter or side-to-side movement of the steering wheel indicates that the tires are out of balance. With the car going in a straight line, make a normal turn to one side, then release pressure on the steering wheel. The car should straighten out and the steering wheel should return to center. If this doesn't happen, it could mean you have binding linkage, insufficient caster (a built-in steering angle) or insufficient steering axis inclination (another built-in steering setting). A careful check of tire surfaces will help you further diagnose front suspension problems.



Tire wear patterns, such as those shown in the tire wear chart, can be a helpful guide to troubleshooting suspension problems. Keep in mind that different brands and tread styles may show different wear patterns on your automobile. Make sure that the tires themselves are not part of the problem. Incorrect tire pressures, tires too wide or too narrow for the rim they are mounted on or tires that are not properly rated for the load of the vehicle can cause considerable change in wear patterns.

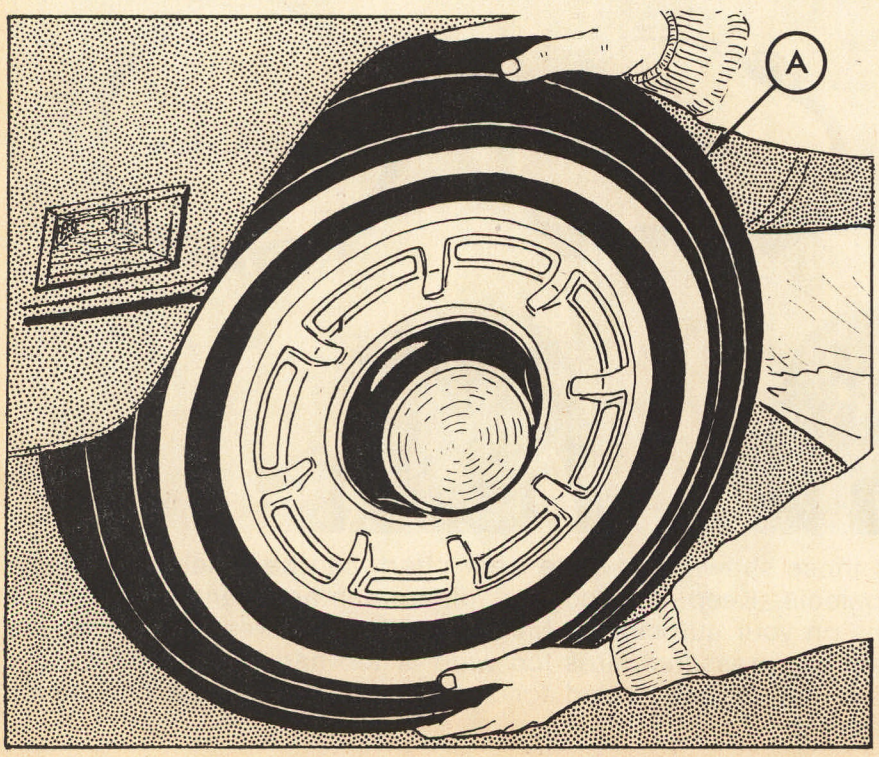
TROUBLESHOOTING FRONT SUSPENSION



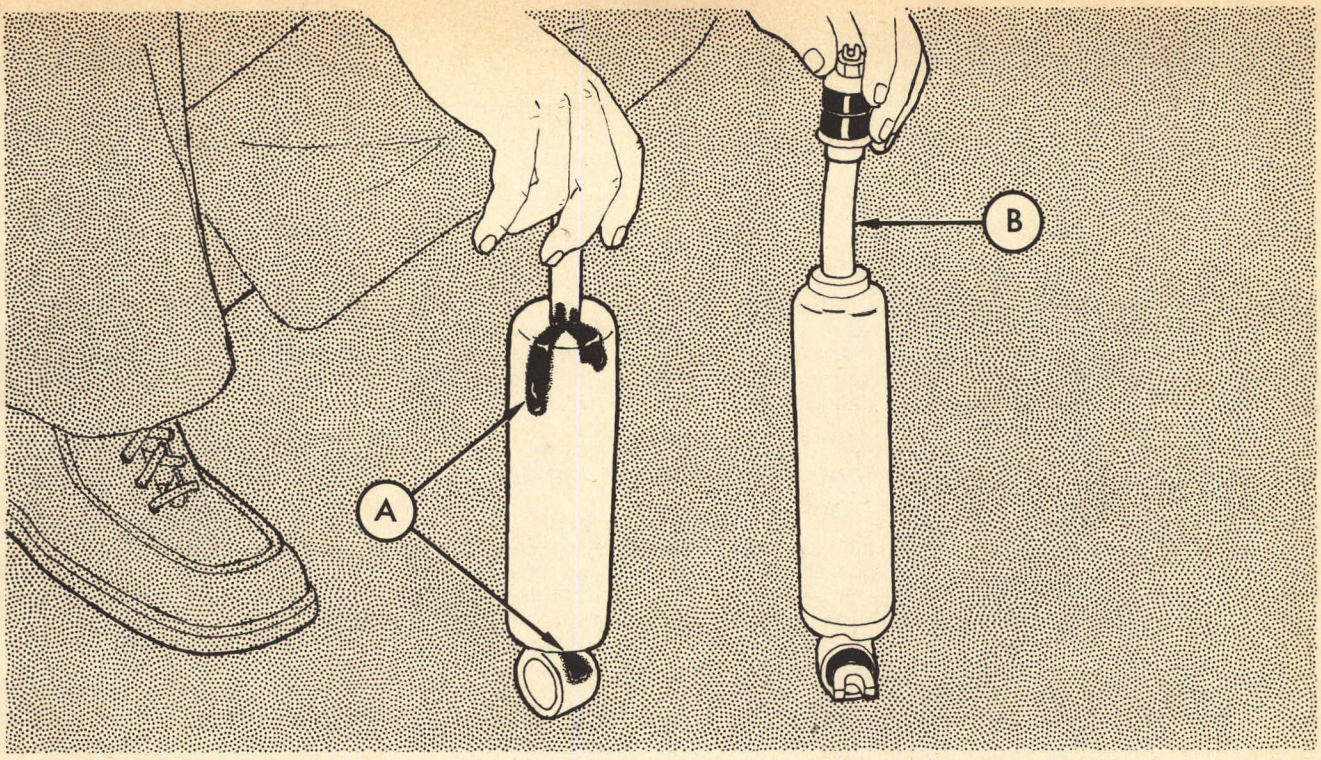
Driving the car over a bumpy surface can give an indication of spring and shock absorber quality. A car that bounces and dips going around a corner probably has worn shock absorbers. Complete suspension travel or "bottoming out" of the suspension when going through a dip at a reasonable speed means that the car should be checked for weak springs and worn shock absorbers. Remember that most American autos have a soft suspension to give a more comfortable ride, so care must be excercised in making a judgment about suspension problems. What seems sluggish or soft may be normal ride qualities.

Excess movement or slack in the steering wheel is a trouble sign. The normal steering wheel should only move an inch or so before the car reacts. Too much "play" is a sign of a worn steering box or steering linkage.

NOTE: EXCESS STEERING WHEEL PLAY CAN OFTEN BE CORRECTED BY ADJUSTING THE STEERING BOX ITSELF.



To further check the suspension, place the car on axle stands or a hydraulic hoist. Then examine the front suspension components for signs of failure or wear. One of the easiest things to check is front wheel bearing wear. Grasp the tire (A) at the top and bottom and try to move it in and out in a vertical plane. If the wheel bearing clearances are excessive, there will be obvious movement and sometimes a clunking sound as the front wheel and drum move on the spindle. Badly worn ball joints can also show up in this check, but they aren't as noticeable.



With the car raised, check the exterior of the shock absorbers for signs of oil leakage (A) or broken or bent connecting ends (B). A final check of shock absorbers can be made by removing the shock absorber from the car and testing it by hand. (See the shop manual for instructions on removing the shock absorber.) Once you have the shock removed, it can easily be tested. Grasp each end of the shock and pull or push the shock from the open position to the closed. The shock should have a smooth action but be very hard to move. If the shock is easy to operate, it is probably worn out and should be replaced.

All the steering linkage should be checked visually to determine if any components are worn or broken. If it is possible to get the automobile raised on a hydraulic rack at a service station, you may be able to check the front steering components by having one person turn the steering wheel while another watches the suspension. If you are alone, you can turn the wheels from underneath, but it is very hard.

In cases where turning the steering wheel while driving produces an audible clunking sound or a binding feeling, raise the hood and have somebody turn the steering wheel while you watch the steering box.

WARNING: IF A SEVERE FRONT SUSPENSION PROBLEM IS SUSPECTED, DO NOT TEST DRIVE THE CAR YOURSELF. TAKE IT TO A QUALIFIED MECHANIC AND LET HIM TEST DRIVE THE CAR OR CHECK IT ON HIS EQUIPMENT. FAILURE TO DO SO MAY RESULT IN AN ACCIDENT.

Some tire wear problems cannot be blamed on the suspension. If severe tire wear indicates a problem, first satisfy yourself that tire inflation is correct and that the wheels themselves are not at fault. A steel rim may become deformed after coming in contact with a curb or other solid object without the driver being aware of the problem. Out-of-round tires or out-of-balance tires and wheels can not only cause severe tire wear but can increase wear of the front suspension parts. One not too common but possible problem is nonuniform tire sizes. This can result in a car that wanders or pulls to one side and unusual tire wear. This usually occurs when the spare tire is a different size than the regular tires and is installed on one of the front wheels.

One of the most important things governing front suspension wear is lubrication. All the moving parts of the front suspension and steering systems are subjected to dirt, water and the effects of road salt in Eastern states. All joints and fittings that require lubrication should be checked carefully for fresh lubrication and should be serviced if necessary. Failure to provide adequate lubrication can result in early failure of your car's suspension and steering components.

Manual Steering

Think back, if you can, to your first hot rod, not your first car, but the "soap box" racer you built from scrap wood and some "borrowed" baby carriage wheels. Steering was no problem. Right? You just made the 2 × 4 front axle pivot on a bolt at the front of the "frame" and steering was only a matter of putting your feet on the ends of the axles; or if you wanted to keep your feet in, you shortened your mother's clothesline and used the rope to steer. It seemed logical enough at the time; after all, didn't all those wagons in the cowboy movies steer something like that? Thankfully, steering gear design has progressed steadily since those wagons went out of favor and "the horseless contraption" was invented.

Faster cars required better handling for those poor roads. And when "balloon" tires and front-wheel brakes were introduced, steering became even harder, and led to the development of the steering box. Essentially, the driver steered a wheel at one end of a shaft, at the other end of which was a set of gears that transferred the motion, through arms and rods, to the wheels.

WORM AND SECTOR, WORM AND WHEEL DESIGN

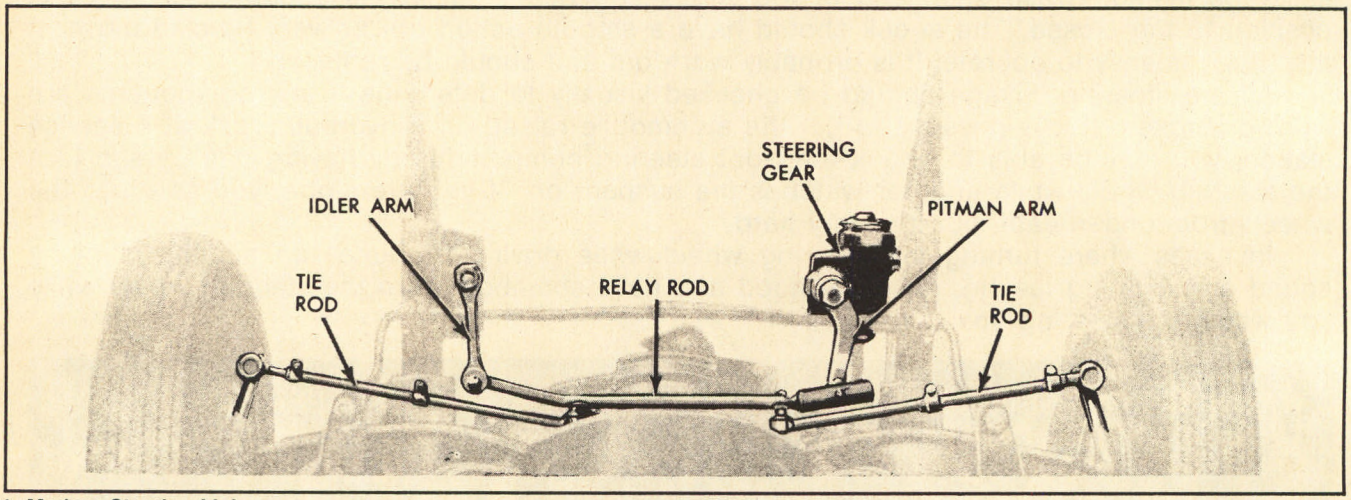
The worm gear was, and still is, almost universal in its use on the steering column shaft. In the worm and wheel design, as the name implies, a toothed wheel meshed with the teeth on the worm, and a shaft connected this wheel with the pitman arm. The worm and sector was simply the same system, but instead of using a wheel, just a piece-of-pie portion of the wheel was used, since within the turning limits of the front wheels most of the wheel-gear could not be utilized.

Friction proved to be the common enemy of all steering designs, and these early types were no exceptions. Most of the loads in the box were concentrated on the gears at their mesh points, and constant lubrication was a necessary drawback. They also required frequent adjustment, and proper alignment became difficult at the mesh point because it was found that the gears wore unevenly. That is, they most often wore out in the straight-ahead position, where they received the most use.

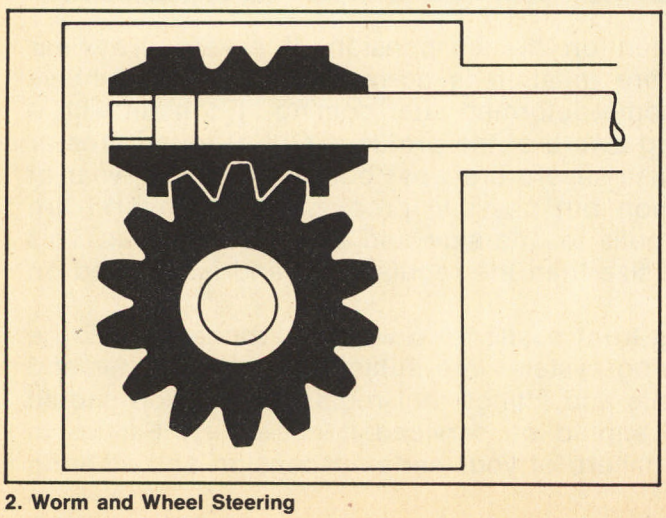
Once the gears were worn, you could adjust them only so much before the gears would bind. The worm and wheel type did at least have the advantage that the wheel could be removed and reinstalled with fresh teeth at the mesh point.

ROSS STEERING

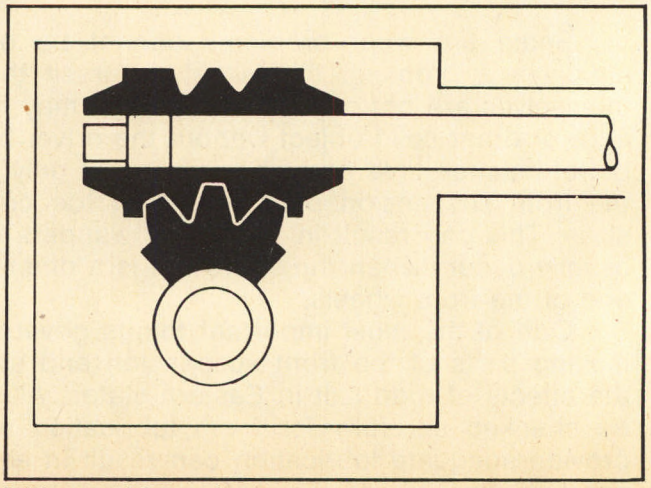
The introduction in 1923 of the Ross cam and lever steering gear was a solid step forward in terms of reduced friction



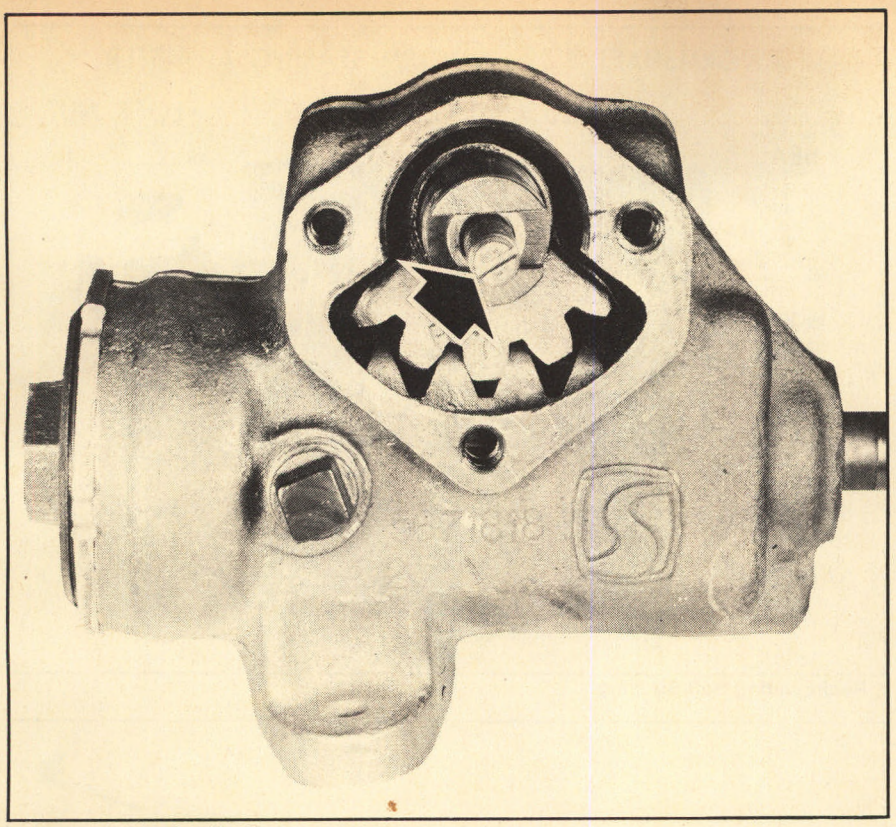
1. Modern Steering Linkage



2. Worm and Wheel Steering



3. Worm and Sector Steering



4. Saginaw Steering Box

1. For the last 20 years, American cars have used steering gear with split tie-rods rather than the older drag link system because of less lost motion and better geometry.

2. The worm and wheel was one of the first automotive steering designs. It proved to be inefficient, because all the friction was concentrated in the mesh area of the gears.

3. A variation of the worm and wheel was the worm and sector, which was cheaper and could be built as a more compact unit than its predecessor.

4. Here's a Saginaw worm and sector box with the side cover removed to expose the gears. Note the adjusting slot (arrow) for mesh load.

and wear. One long groove (the cam) spiralled around the end of the steering shaft and a lever on the pitman shaft had a peg on it that fit this groove. As the steering wheel was turned, the peg was forced to ride up or down the shaft in the groove, and this action turned the pitman shaft and arm.

The Ross steering was a very good compromise; it was *almost* irreversible. It was difficult for motion to be passed from the wheels back up through the steering wheel, but enough was felt at the wheel to give the driver that important "feel of the road" which gives him confidence in his control.

WORM AND ROLLER

Friction was still a factor to be reckoned with, though, as cars got heavier, tires got bigger and tire pressures became lower for a better ride. It wasn't just that it was becoming harder to steer the car, but friction and wear within the gearbox was increasing again with these greater loads. So the people over at the Saginaw Steering Division of General Motors started making worm and roller steering in 1926 for the heavy Cadillacs. Basically, the worm on the steering shaft was hourglass-shaped; it was thicker at the ends than in the middle. Instead of a curved sector meshing with it, there was a roller, like a single large gear tooth, which was perpendicular to the steering shaft. It was mounted in roller bearings in a yoke that was part of the pitman arm shaft. These bearings took much of the load and the big roller distributed the wear more evenly. The design was so efficient that it is still used today.

RECIRCULATING-BALL STEERING GEAR

By far the most widely used steering gear today is the recirculating-ball type, introduced on the 1940 Cadillac. Another development by Saginaw, it was basically an improvement of the screw-and-nut design that had been around for many years. A long worm gear was on the bottom of the steering shaft, on which a large, coarse-threaded nut was fitted. The nut was inside a collar or sleeve that could slide back and forth inside the box, and this sleeve had teeth on one side that meshed with a sector gear on the pitman shaft. As the steering shaft was turned, the nut moved up and down the worm gear threads and pushed the sleeve up and down with it, so that the teeth on the sleeve moved the sector and turned the pitman arm.

Actually, it was a lot less complicated than it sounds, and had a number of features that have appealed to later engineers. One of the best features was its irreversibility; only enough road feel came back through the steering for good control. And it considerably reduced the driver effort involved in steering even such "boat anchors" as the 16-cylinder Cadillacs on which it was used.

That old specter of friction is the area modern engineers have so improved in this basically good design, which is where the recirculating balls come in. The grooves in the worm and inside the nut were machined for ball bearings, so that, in a sense, the balls performed the function of threads and absorbed the steering gear loads and friction. As the car was steered to the right, the balls would circulate in one direction, and in the opposite direction during a left-hand turn. Two tubes connected four holes in the nut/sleeve unit so that the balls could circulate over and over again and distribute the wear evenly among all of them.

Friction was reduced so much that steering was made much easier without having to slow down the gear ratio, which as we have said results in more lock-to-lock turns for the driver. Except for power steering, this represents the furthest advancement of steering gear design thus far, at least on domestic cars.

RACK AND PINION STEERING

Across the Atlantic "river," car manufacturers through the years have utilized some of the same steering systems as we have, though the light weight and smaller size of their cars have permitted the use of generally faster steering ratios. Perhaps the most interesting and different design is the rack and pinion type, seldom found on American cars, but common on most foreign cars and many different kinds of race cars.

In this case the gear on the steering column is similar to the pinion gear in a differential—cut on an angle, and meshed with a steer bar (the rack) toothed on one side. The rack is mounted parallel to the front axle, and as the steering wheel is turned, it operates directly on the steering linkage without the use of a pitman arm or draglink. It's fast, simple to work on, and lightweight because it eliminates some of the usual linkage, which are the reasons it has been such a favorite on race cars and sports cars. Its one drawback is that it has very little inherent reversibility, but in a racing machine the driver isn't worried about comfort or parking ability and is usually interested in more feedback or road feel than the average driver. Rack and pinion steering is thus a natural. Its quick action has made it the standard system on most imported sports cars, which are small and light, and now that Detroit is moving back into the small car business, it's turning to rack and pinion for Pinto-size cars.

For passenger car installations, a compromise is often made by using a shock absorber-type damper on the linkage to reduce the reversibility. Since the damper's action is proportional to the amount of force put on it, small road shocks (desirable road feel) can be felt throughout the steering, but fast, hard, driver-jerking bumps are dampened.

Manual Steering

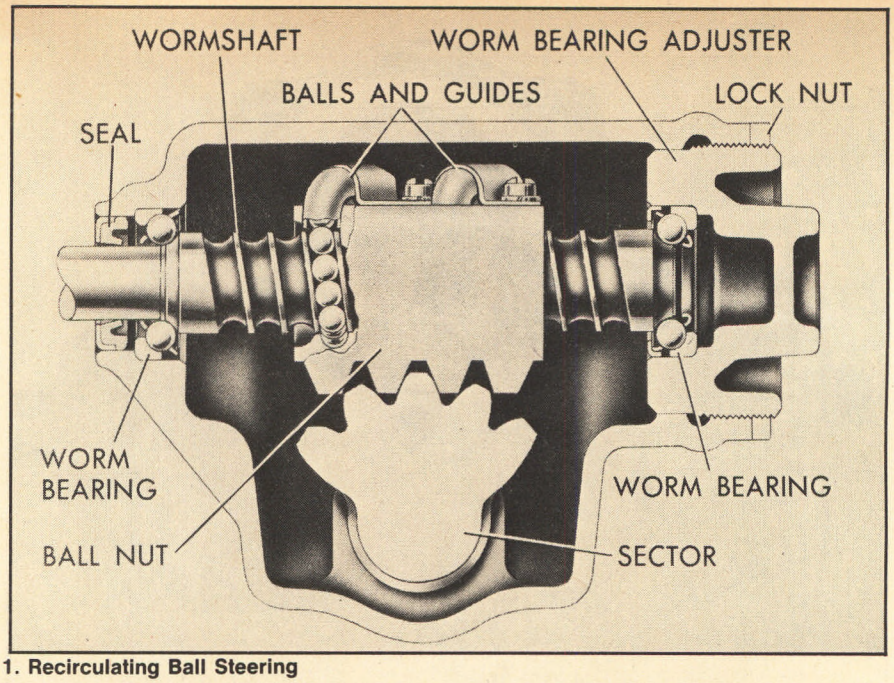
Currently, however, manual steering gears are made in three basic types. The Gemmer Worm and Roller Gear was used on Chrysler Corp. cars until the end of 1961, and on American Ramblers to date. General Motors passenger cars and Rambler, except American, use the Saginaw Recirculating-Ball type. Chrysler Corp. cars, 1962 and up, also have a recirculating-ball type, and so do Ford products. A seldom-used type is the Ross Cam and Lever, used on Jeep and pre-'61 Studebakers.

MAINTENANCE

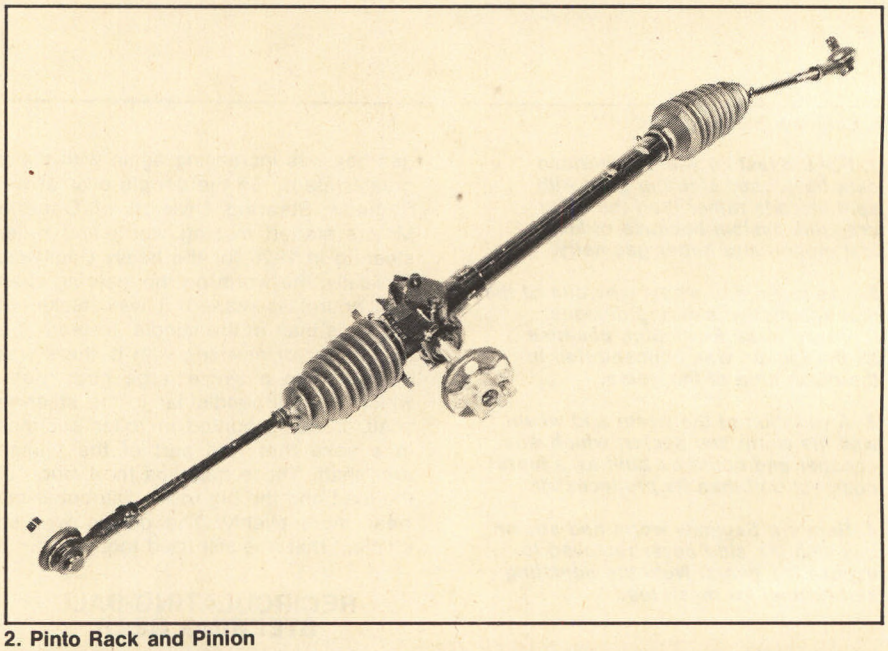
In most cases, you won't have too many complaints about the steering gear on your car, mainly because modern steering systems are well designed and relatively trouble-free, and besides, you'll probably be spending all of your attention on good stuff like the engine and suspension. Taking care of your steering amounts to no more than checking periodically, keeping it full of grease or 90W oil, and making adjustments when necessary. Rarely will you ever want to *rebuild* a steering box. It would prove to be a pain in the bippy. Most guys are content to visit their friendly/unfriendly neighborhood junkyard for a replacement unit if something goes seriously wrong with it. You could buy a good used steering box and column for what it would cost to replace even one of the gears in your present box with a new factory unit. But, as with anything you buy used or from a wrecking yard, you have to be careful or you'll wind up spending good bucks for an item that later reveals itself to be pure mung.

If you do buy steering in a junkyard, check it over as carefully as you would select a used transmission, even to taking off the box cover and washing it with solvent so you can inspect the teeth on the gears. Inspect the box for defects, cracks, welds, etc., and if it's still in a car, try it out to see if it binds or has any play in it. If you're getting one from another model or year than your own car, see how many turns it is from lock to lock so you can determine if it has the ratio you want.

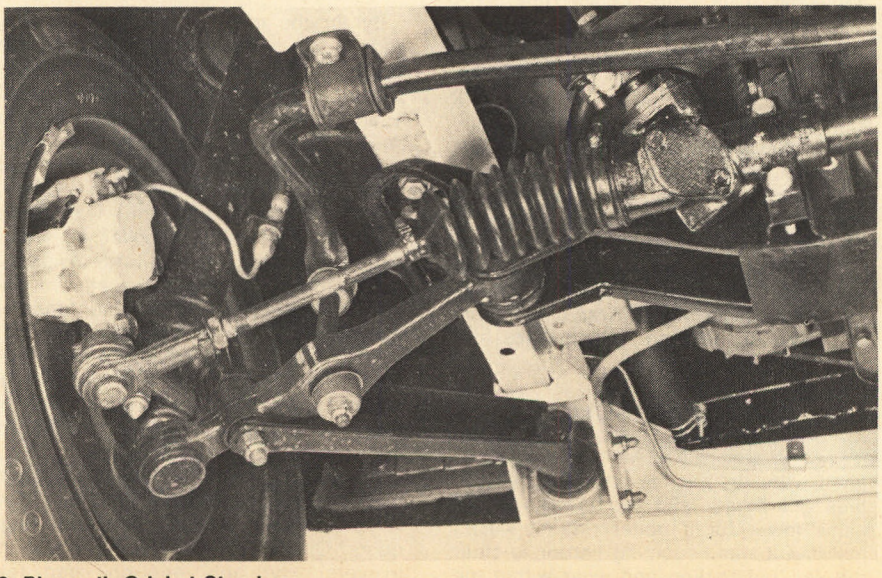
Before you start thinking about throwing out your steering and replacing it, check into it thoroughly, and even before attacking your steering box, try to determine first if it isn't something else which



1. Recirculating Ball Steering



2. Pinto Rack and Pinion

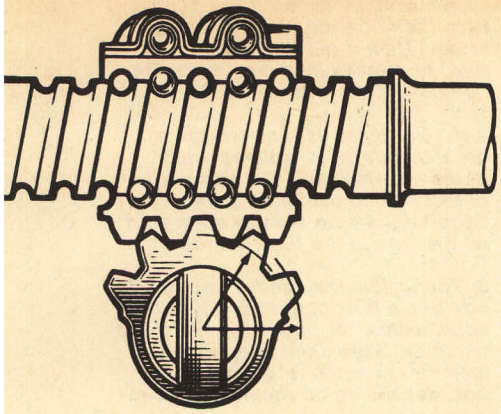


3. Plymouth Cricket Steering

1. The recirculating-ball steering mechanism was first used in 1940. It offered extremely low friction and is the most common type of manual box being used today by Detroit.

2. One of the most popular foreign car steering designs is the rack and pinion. Lacking irreversibility, it is often used with a steering damper. This is steering gear from Ford Pinto, one of few U.S. cars using it.

3. Part of the simplicity of the rack and pinion design is that it is connected directly to the tie-rods, so there is no need for idler arms or relay rods. This is Cricket.



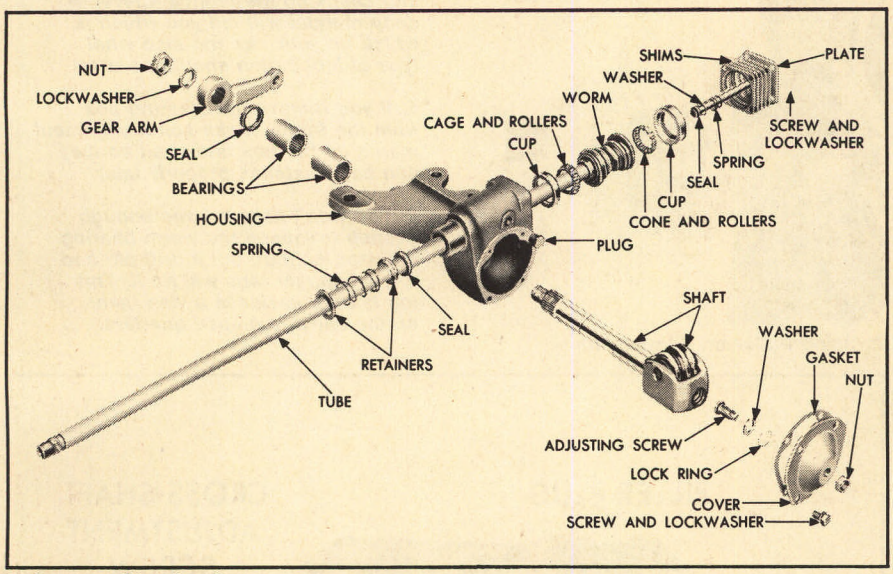
4. Variable-Ratio Steering gear

may be affecting the handling or steering. Things like poor shocks, unbalanced wheels, a misaligned front end, bad wheel bearings, or improper tire pressure can produce the same symptoms as defective steering gear.

If everything else checks out, then inspect your tie-rod ends and idler arms. As trouble-free and long lasting as these parts are, they wear out long before your steering box. Jack up the front end or put the car on a hoist and push up and down on the idler arm. If it's loose, pull it off and inspect it. Usually there is a bushing in the end that should be replaced. Tie-rod maintenance involves pushing up and down on the end of the tie-rod, checking for play just as with the idler arm. To remove them you may have to borrow a mechanic's "tuning fork" or "pickle fork," which is a heavy steel bar forked at the end. It's machined at an angle, like a wedge, so that you can put the fork between the tie-rod end and the steering arm. Hitting the end of the bar with a hammer forces the stud of the tie-rod end out of its socket in the steering arm. Above all, the most important thing to remember when doing any work on the front suspension or steering is to *never* leave out the cotter pins. The life you save definitely will be your own.

GEMMER WORM AND ROLLER

The worm is an integral part of the steering shaft, being hourglass shape, or concave in the middle. It is supported at both ends by tapered roller bearings. The cross-shaft has a triple roller (instead of a sector gear) which fits into the teeth of the worm. An adjustment screw in the cover permits cross-shaft end-play adjustment which determines play between roller and worm. The pitman arm is fastened with a master spline

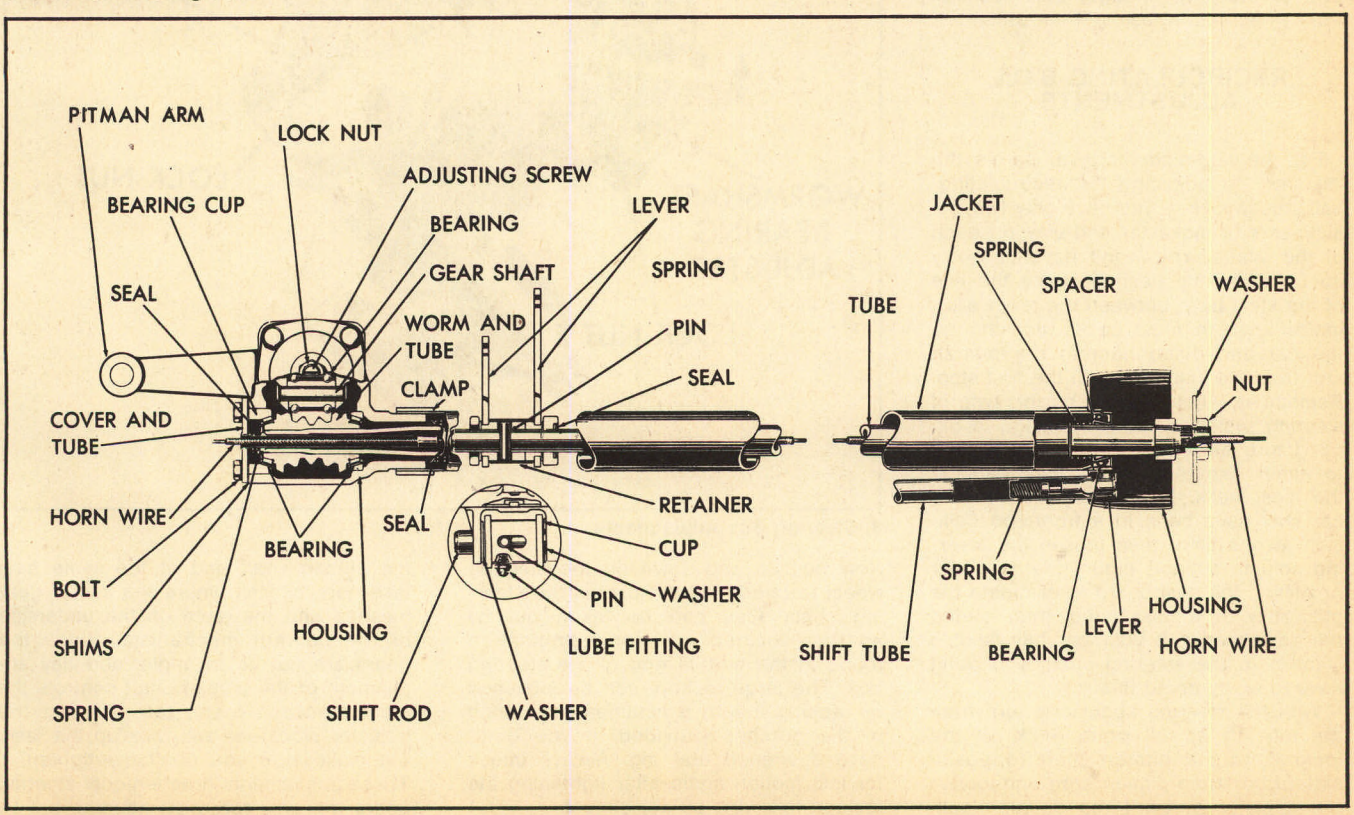


5. Gemmer Steering Box

4. The Dodge Colt, another mini-car using quick steering, has a variable ratio (15.58-18.18) achieved by a specially contoured worm gear. It uses recirculating balls to attain low friction during operation.

5. This exploded view of Gemmer box shows use of shims to adjust worm gear in the housing. You'll find a box like this on many older cars, but most had only bushings, no needle bearings, on cross-shaft.

6. The Gemmer worm and roller design was used by Chrysler for many years. Cutaway drawing shows construction of box, mast jacket and shift tube.



6. Chrysler Worm and Roller

to the roller shaft by means of a large end nut.

Worm bearing adjustment: If adjustment is necessary, first disconnect the steering linkage from the pitman arm. To eliminate end-play in the steering shaft, loosen the four end cover plate screws, then loosen the cover plate and separate the shims with a knife (be careful not to damage the shims). Remove one shim at a time, retighten the screws, and check for end-play by turning the steering wheel full right and left. Repeat this procedure until there is no end-play and no noticeable tightness in the wheel movement to full right and left. Retighten all four screws. Then check bearing preload with a spring scale on the rim of the steering wheel. If the pull is less than 1½ lbs., remove another shim and repeat operation. If the pull is more than 1½ lbs., add shims to decrease pre-load until satisfactory. Be sure all screws are tight when testing with the spring scale.

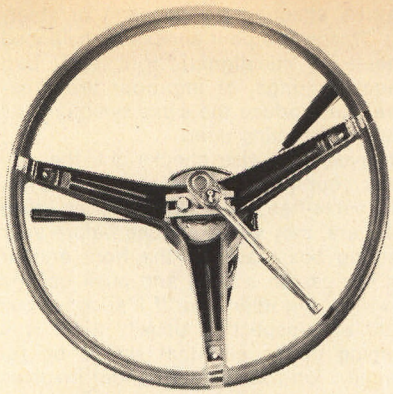
Cross-shaft adjustment: Loosen the cross-shaft adjusting screw locknut in the cover. With the steering wheel in center position, tighten the adjustment screw slightly. Check amount of end-play by grasping the pitman arm. When end-play has been removed, use spring scale again on the steering wheel rim; if there is more than a 1-lb. pull above the first scale reading, loosen the adjustment screw slightly. **Caution:** *Do not overtighten.* The steering wheel should turn freely from one extreme to the other without binding or stiffness. When satisfied, tighten lock nut on adjusting screw. Recheck with scale.

Then fill the steering wheel box with proper lubricant. Reconnect the pitman arm to steering linkage, and recheck front wheel toe-in; adjust if necessary.

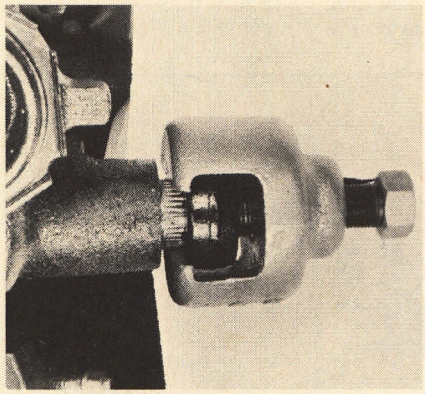
RECIRCULATING-BALL ADJUSTMENTS

For the late-model crowd, here's the "skinny" on adjusting the recirculating-ball steering. Here you have only two adjustments to make for end-play on each of the shafts. You won't have to worry about worm/nut mesh because the use of the steel balls between the teeth eliminates wear in most cases. Jacking up the car and disconnecting the pitman arm from the linkage is still the first step. Remember, when working on this type of steering system when the linkage is off, don't turn the steering wheel *hard* over to either extreme or you may damage the steel balls. If you suspect that the car may have been in a front-end collision at one time, then loosen the steering column support mount that is under or behind the dashboard to eliminate the possibility of a misaligned shaft during the adjustments. If your car has flexible U-joints in the steering shaft, you don't have to worry about this.

With the steering about one turn from the full left or full right, back off the locknut on the pitman shaft (opposite side of box from pitman arm) and loosen the adjuster a few turns counterclockwise to take the mesh load off the gears.



1. Removing Steering Wheel



2. Using Puller on Pitman Arm

1. The horn button ring can usually be removed by taking a few screws from the backside of the steering wheel. Then a puller like this is used to remove the wheel once the large shaft nut is taken off.

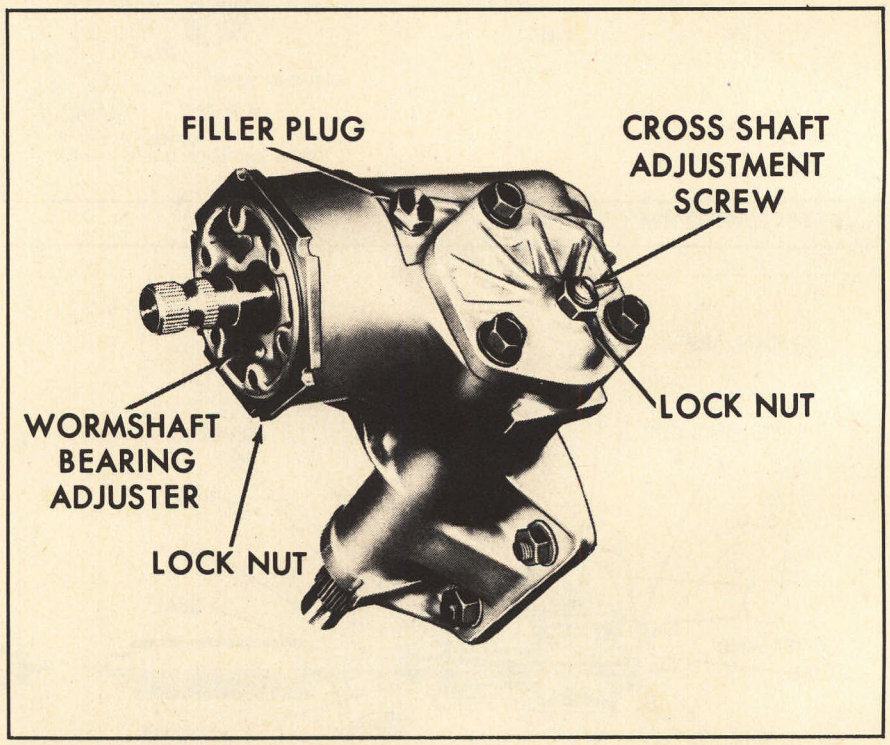
2. A gear puller is required to get Pitman arm off splined shaft of the steering box. The same type of tool is also useful for pulling tie-rod ends from spindle arms with no damage to the tie-rod ends.

3. The typical late-model steering box has a filler plug and only two adjustments, for bearing preload and end-play. Wormshaft bearing nuts may be at the top or bottom of the box, depending on the make of car.

4. On some late-model boxes, there are two different holes for filling and checking the lubricant level. A shop manual will tell you which is which on your car and also what type of lubrication should be used.

5. If you remove the steering box from the frame, make some alignment marks on the box and shaft so they can be reinstalled properly later.

6. You won't have a large enough wrench to loosen the worm bearing adjuster locknut, but a drift pin and a few hammer taps will do it. This job is a lot easier in a vise than on the car in cramped quarters.



3. Steering Box Adjustments

Now pull up and down on the steering wheel to check for end-play in the steering shaft. Play can be taken out by another locknut/adjuster combination found at the bottom end of the steering box. The large locknut can be loosened by tapping it with a hammer and punch in the notches provided, if you don't have a wrench that big. Always check for lost motion again after tightening the locknut following an adjustment.

Now you can adjust the end-play in the pitman shaft and at the same time take care of lash where the sector gear meshes with the teeth on the underside of the ball-nut mechanism. Since the gears are cut at an angle, end-play adjustment of the pitman shaft controls the mesh between them, too. Turning the adjuster *clockwise* will take up the lash, but make sure you don't overtighten it. These adjustments of late-model steering gears will only rarely be needed, but by all rights they should be made with the

use of a pounds-pressure gauge on the steering wheel to measure drag or bind. Assuming that you don't have such a gauge, though, you can do it yourself as outlined above, or have it done at your dealer's garage.

Lubrication for the steering box (about SAE 90W) can be purchased at most parts stores or you can have it put in at a garage, since you don't need very much. Some steering boxes use chassis grease. If there is no filler plug on the box, or if it has a grease-gun-type lube fitting, it probably should have chassis grease. Using 90W in a box designed for chassis grease will result in a big mess because the 90W will probably leak out profusely.

STEERING WHEEL REMOVAL

The removal of the horn sounding ring or button can sometimes be more difficult and perplexing than the removal of the steering wheel. One of the cardinal rules of the good mechanic is: *Never use force to remove units or parts, unless you know how.* Forcing in the wrong place can lead to damage or breakage, and can cost embarrassment, time, and money.

To remove the horn switch or steering wheel, first disconnect the battery to prevent the horn from sounding. *In all cases a wheel puller should be used to remove the steering wheel.* Before removing the wheel, make a scribe mark on the end of the steering wheel shaft and on the wheel hub, so the wheel can be reinstalled correctly. Some cars have a blind spline for this purpose.

REMOVING THE STEERING BOX AND COLUMN

If all of the above adjustments have failed to correct any problems you suspect are coming from the box, then you haven't much choice but to replace the unit. It may look like it's going to be a beast of a job (it really isn't), but keep telling yourself that you need the exercise, or consider it as a challenge. Naturally, you first have to take that steering wheel off, and for this you're going to need a steering wheel puller or gear puller because it's on there pretty tight. You'll need it to pull the pitman arm from its shaft for the same reason.

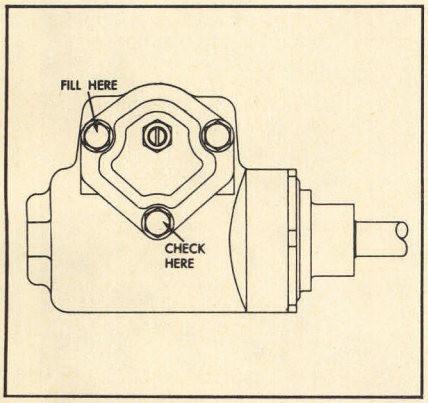
Before starting, determine if the gear and column can be removed from the top—by raising it up through the dash over the driver's seat—or by dropping it down through the floor or dash, beside the engine and out from below the car. If necessary to drop it out through the bottom, arrangements must be made to jack up the front end of the car to permit the removal of the gear and also the column assembly.

Once the removal route has been determined, here are the steps you should follow:

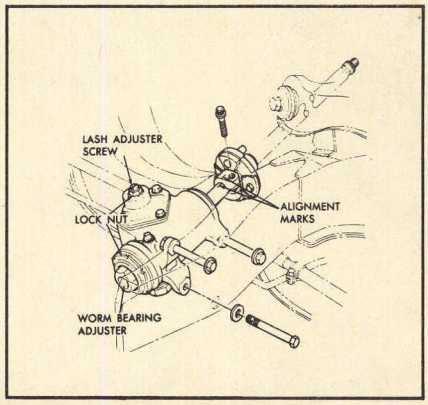
1. Place protective cover over the front seat.
2. Disconnect battery cables.
3. Disconnect wires at bottom of the steering column, one at a time and tag each wire carefully.
4. Disconnect steering linkage from pitman arm.
5. Remove jacket tube clamps at steering gear housing (if any).
6. Disengage steering shaft flange from flexible housing. Note: Some late cars have a flex connection between gear shaft and steering wheel shaft. This will make it unnecessary to disturb the steering column and wheel.
7. Remove support clamp at instrument panel.
8. Remove horn and signal wires from steering column below instrument panel.
9. Remove horn ring and steering wheel—a wheel puller is needed.
10. Remove dust shield at firewall.
11. Remove floor opening panel (if any exist).
12. If car has manual shift lever on steering column, disconnect gear shift rods that are at the bottom of the steering column.
13. Disconnect neutral safety switch wire at bottom of column and tag it.
14. Unfasten steering gear from the frame (attached with three or four bolts).
15. If car has automatic transmission, disconnect gear indicator from the dash dial.

After disconnecting the electrical and shift linkage connections from the mast jacket—which is the column or tube covering the steering shaft—you can unbolt the box from the frame, the mast jacket from the dash bracket, and pull the mast jacket into the inside of the car and off. The shift arms on it can be worked through the flexible sealing around the steering column at the firewall. Now the box itself and the steering shaft can be removed from the frame.

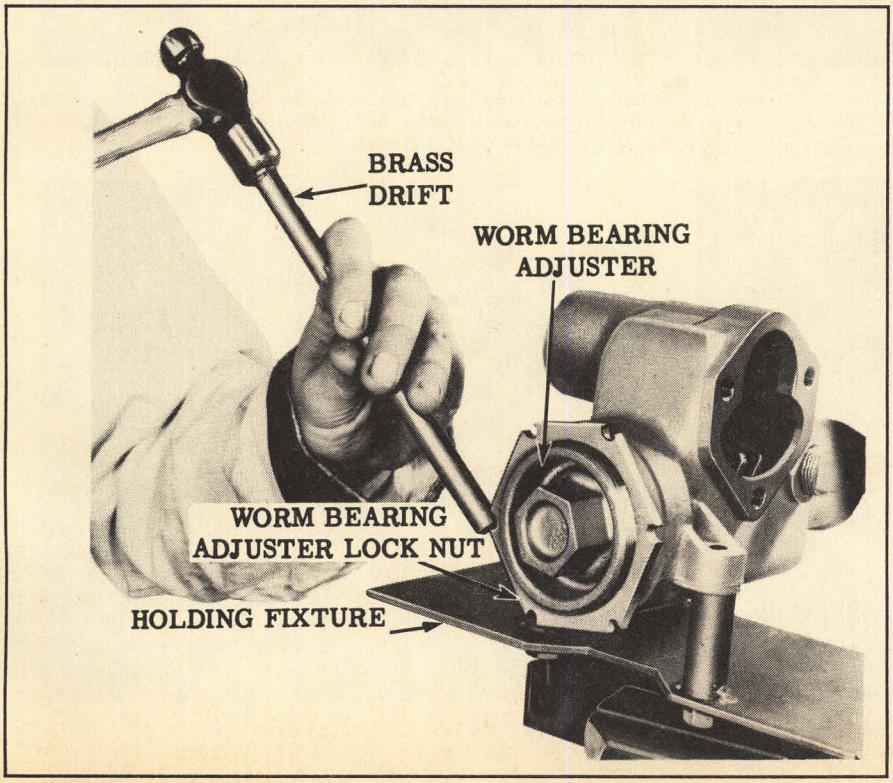
Because safety is so important, the collapsible steering column has become a standard item on new cars. Some have a steel mesh section in the middle that folds up in a crash, while later versions utilize two sections held together with plastic pins that shear under impact, telescoping the two sections. When working with such a column, be careful not to collapse it by accident (no pun intended). Don't yank on it too hard, and don't use a hammer on the shaft to loosen steering wheel when removing it.



4. Lubrication Plugs



5. Attaching Box to Frame



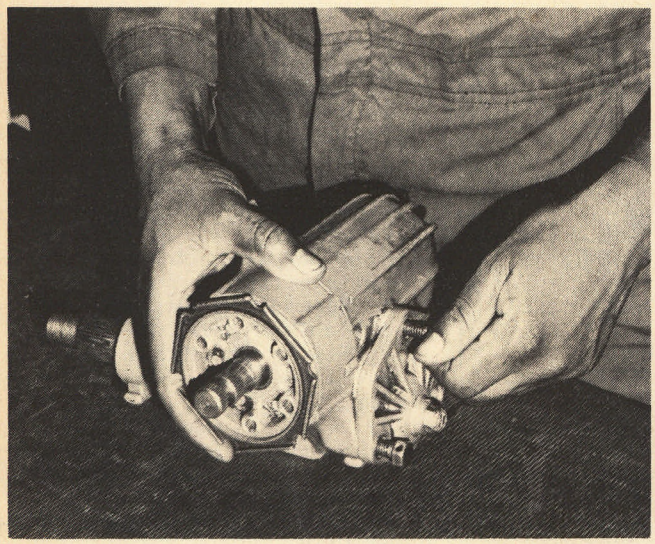
6. Loosening Adjuster Locknut

Steering Box Overhaul

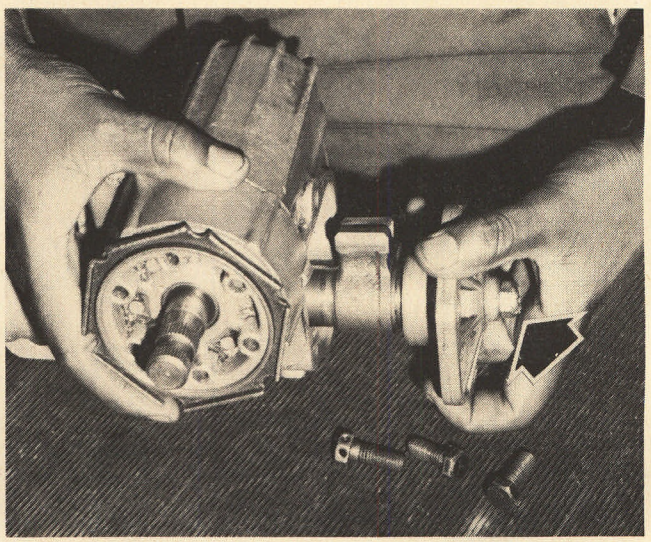
Most cars today use recirculating-ball steering, which is generally so trouble-free that all it should ever need is an occasional adjustment. We're presenting this how-to for those of you who *do* have trouble, because sometimes adjusting won't clear up the steering slop.

Once you've determined that it is the box and not some other part of the steering linkage, remove the box from the frame. This procedure will differ with every make of car, so you may want to check in a shop manual. Once on your bench and cleaned up enough to work on, a manual steering box is fairly simple to rebuild. You disassemble it, inspect and clean the old parts, replace the worn parts with new ones, and lube the parts and reassemble. The important thing to remember while you have your steering box apart is to keep all parts spotlessly clean and lubricated with steering gear lube, *not* gear oil. It's a lot of work sometimes to take out and reinstall a steering box, but in the end, rebuilding will "set you straight" for years.

HOW-TO: Over hauling Steering Box

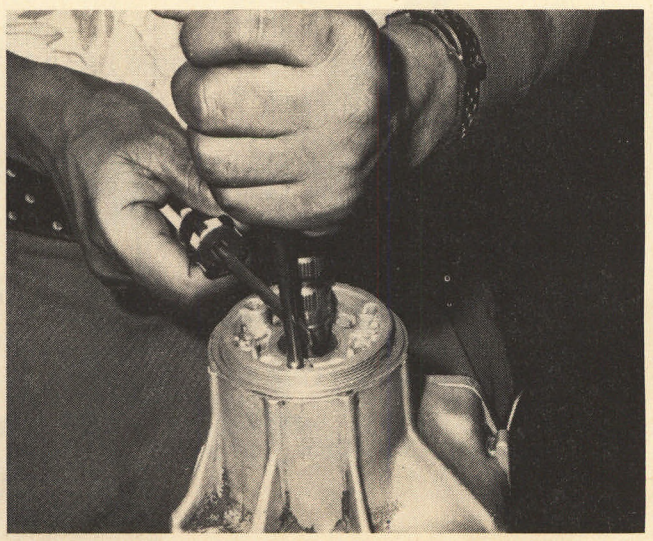


1. This is a Mopar recirculating-ball steering box, but almost all modern boxes are similar. First step is to thoroughly clean box and remove cross-shaft cover screws.



2. Before removing the cross-shaft cover, back off a few turns on the cross-shaft adjuster nut (arrow) to take load off gears, and turn gears to center of travel.

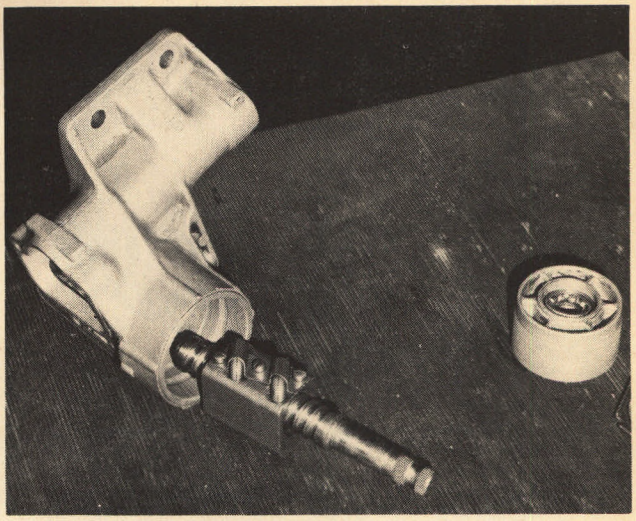
3. With the cross-shaft and cross-shaft bearing and cover assembly removed, use a hammer and punch to get lockring loose on wormshaft bearing adjuster nut.



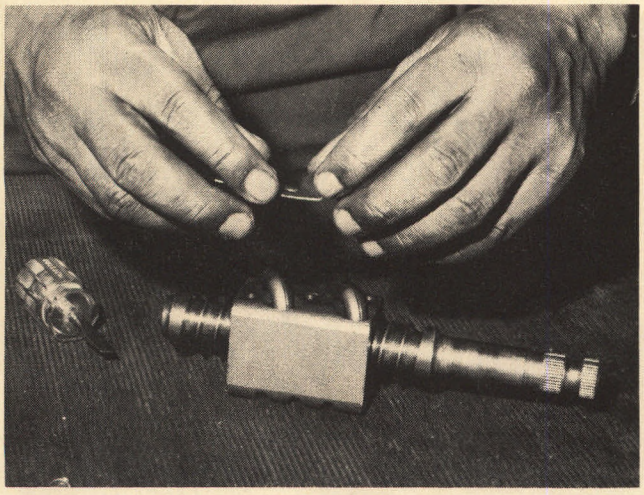
4. If you don't have the factory spanner wrench to use, the wormshaft adjuster can be loosened by using two screwdrivers and prying against the wormshaft.

HOW-TO: Overhauling Steering Box

5. The wormshaft adjuster can now be removed after it is threaded all the way out of the housing. Since it is aluminum, take care not to damage the threads.

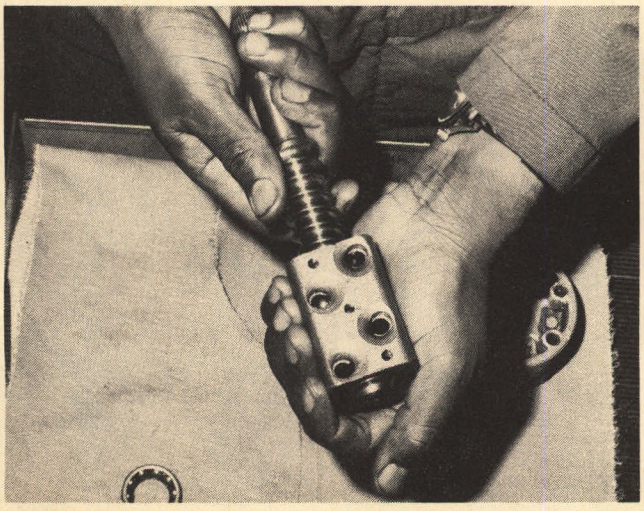


6. Your steering box probably won't be as clean as this demonstrator unit at Los Angeles' National Technical Schools, but here's the recirculating-ball mechanism.

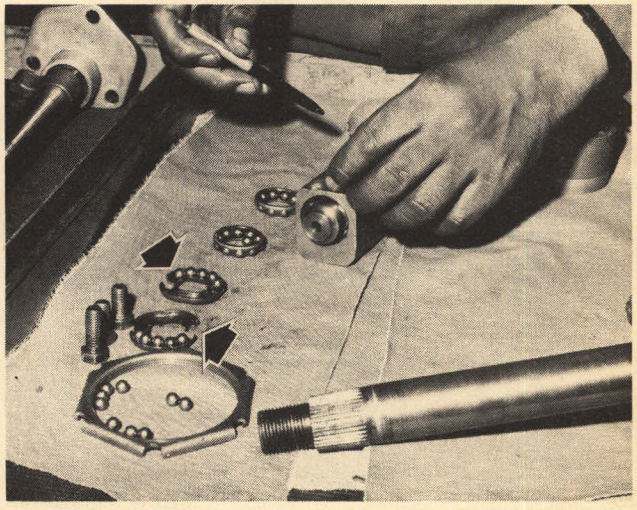


7. The secret of the recirculating-ball steering is in the ball bearings which take the pressure of the mating gears. Remove cover and ball-return guides from nut.

8. You'll have to run the nut up and down the wormshaft to get the ball bearings to come out, but never run the nut to extreme end of wormshaft with balls in place.

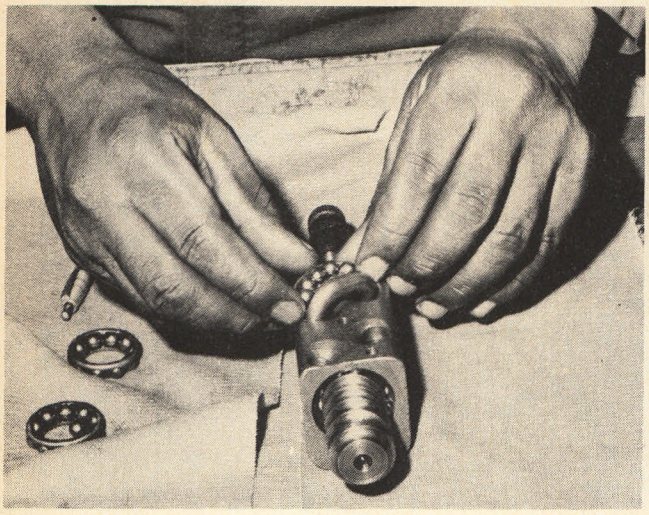


9. With balls out, wormshaft can be removed. After an inspection of nut, wormshaft and balls for any wear or pitting, you can lube and reassemble nut and wormshaft.

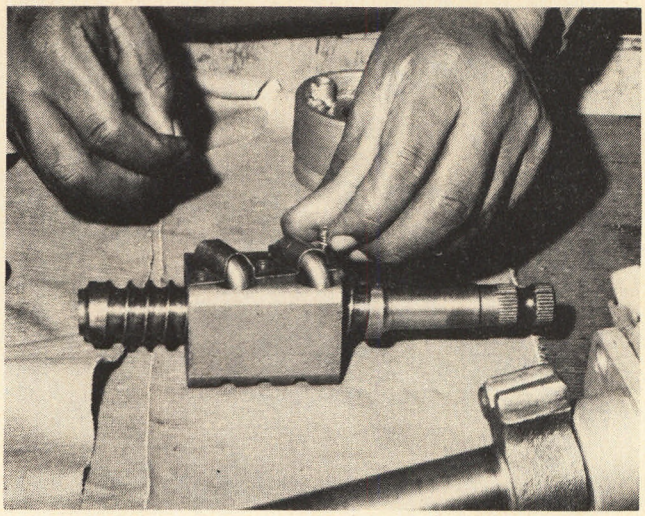


10. Eight balls should be greased and kept in the return guides (arrows). The remaining balls should be put in two equal groups and inserted into the wormshaft nut.

HOW-TO: Overhauling Steering Box

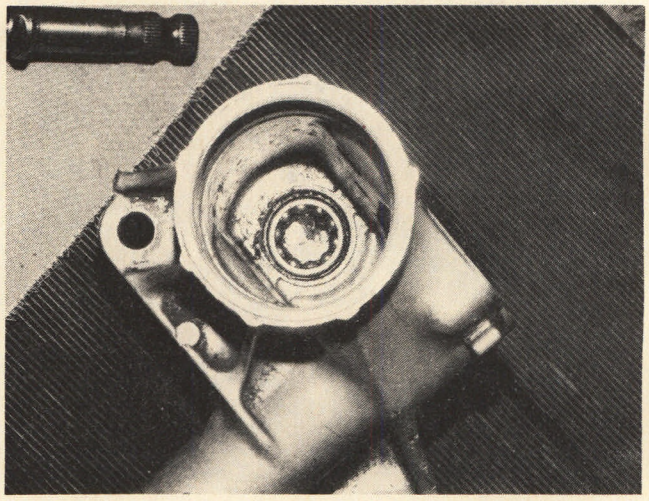


11. When an equal loop of balls has been made in each passage through the nut, the ball-return guides and other four balls can be carefully reinstalled.

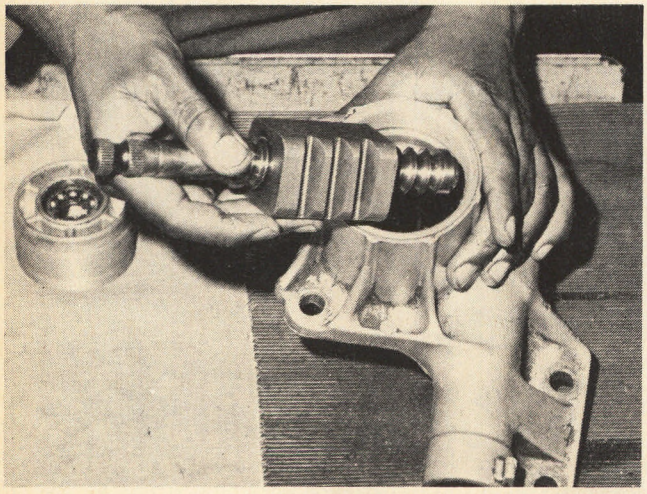


12. When all the ball bearings are in place, the ball-return guides can be secured with retainer. Check at this point for free operation of wormshaft inside nut.

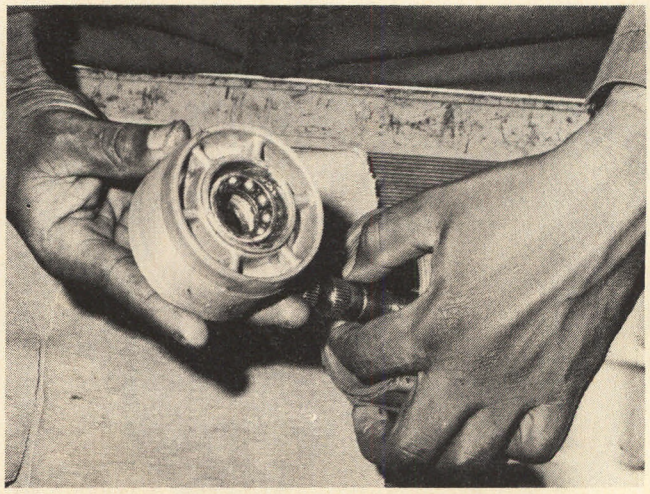
13. Coat a new thrust bearing (for the wormshaft) with grease, working it in as you would with a wheel bearing. All other parts should be coated with steering lube.



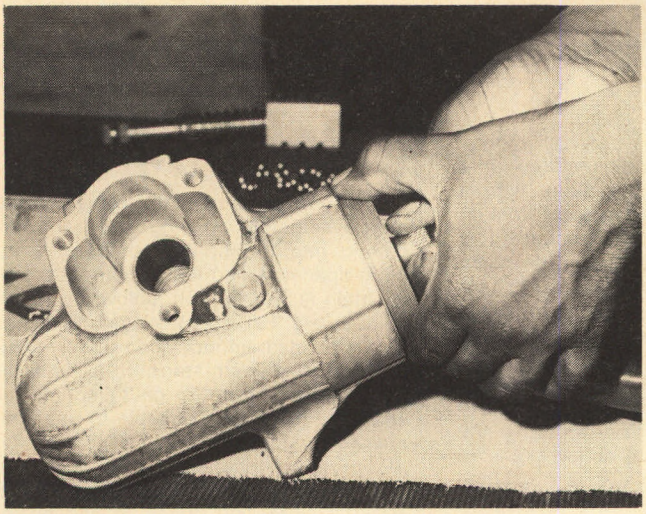
14. After determining that housing is clean and in good shape with no cracks, install the thrust bearing in cup in the lower portion of the steering box.



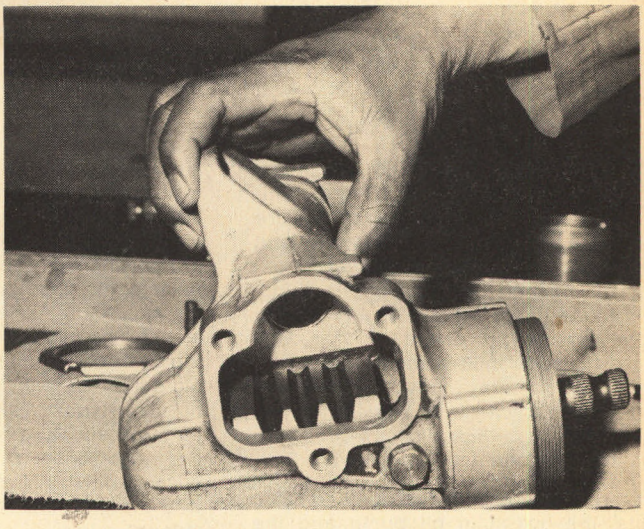
15. Being careful to keep the ball-nut centered on the worm-shaft, slip the assembly carefully into the box, with the end of the wormshaft resting in thrust bearing.



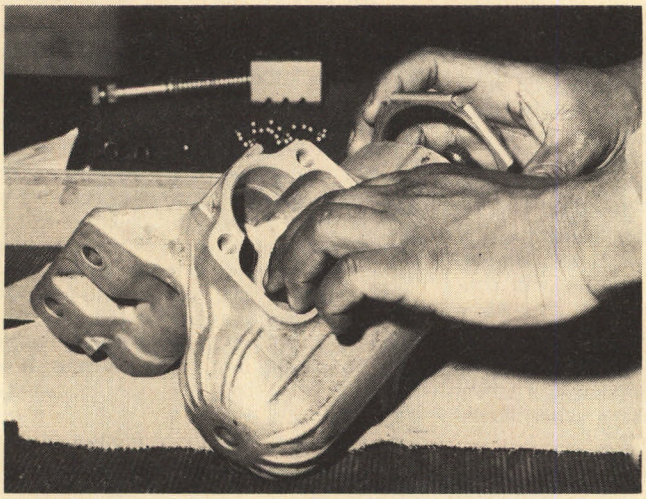
16. Another wormshaft bearing is greased and placed in adjuster. Tape worm splines to protect seal and slide lubed adjuster over wormshaft and thread into housing.



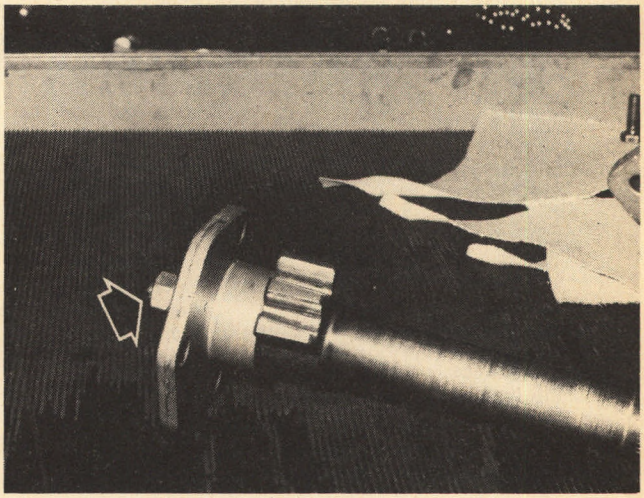
17. Threads of both housing and adjuster should be lubed, then adjuster should be tightened to 50 ft.-lbs. to seat the wormshaft bearings, then backed off to no load.



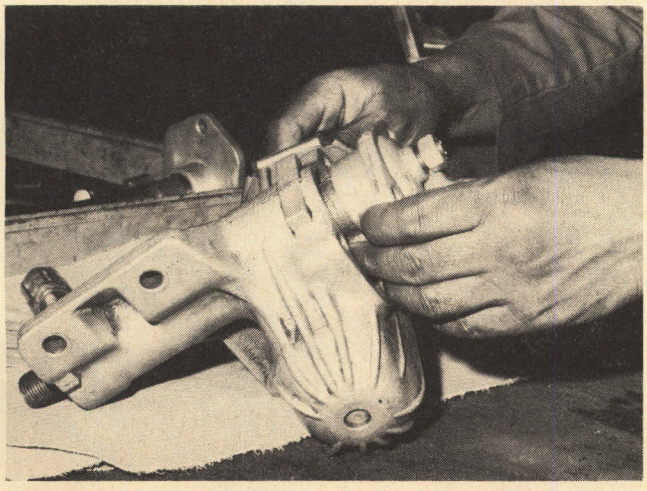
18. The ball-nut should now be centered in its travel, which means that the central groove should line up with lower cross-shaft cover bolt-hole and cross-shaft hole.



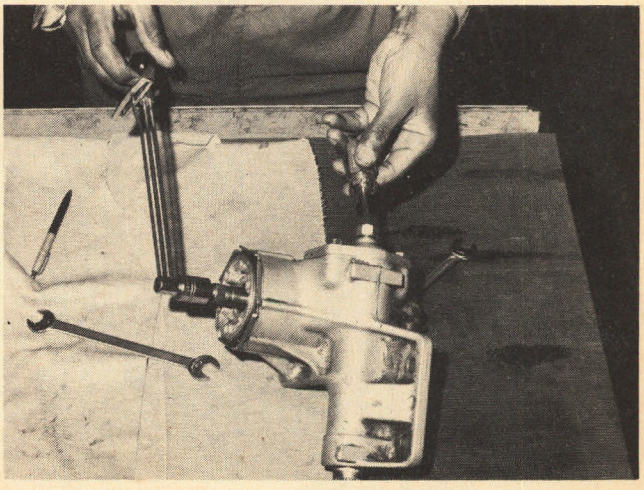
19. After seating the thrust bearings, tighten the wormshaft adjuster again until the "preload" on the bearings is between 1 and 4½ in.-lbs.; then install locknut.



20. The teeth of the sector gear and the wormshaft nut have matching tapers. Cross-shaft adjuster (arrow) puts right amount of mesh-load on the mating gear teeth.



21. With locknut loose, cross-shaft can be slid into the centered wormshaft nut and cross-shaft cover can be loosened on shaft and bolted down to the housing.



22. Final adjustment of cross-shaft should take 8-11 in.-lbs. to turn wormshaft when wormshaft is ¼-turn off-center. Tighten cross-shaft adjuster nut to 35 ft.-lbs.

Power Steering

As the modern automobile has grown longer, heavier and more complex, it has also become more and more difficult to maneuver in and out of city traffic. Even high-speed freeway driving can quickly become tiring. To reduce driver fatigue, make parking more manageable, and attract the lady of the house to their particular products, auto manufacturers have increasingly equipped their cars with power steering, either as standard equipment or as an optional (and often advisable) extra.

Power steering includes two basic units: the hydraulic oil pump and the steering unit. Mounted at the front, the hydraulic pump is belt driven by the engine and supplies oil pressure as needed to the steering unit. On some earlier models of the mid-1950 period, and the current Ford-Lincoln-Mercury line, the power steering unit is an "assist" or linkage type and can be replaced without removing the entire steering assembly. On others the unit is coaxial (Chrysler) or otherwise an integral part of the gearbox.

POWER STEERING HYDRAULIC PUMPS

All power steering pumps are constant-displacement type, delivering from 650 to 1300 lbs. pressure, depending upon the type and make of the system and the car. Special power steering fluid or Type "A" automatic transmission fluid is used. This fluid is stored in a reservoir attached to the pump with a filter in the reservoir to prevent foreign matter from entering the system. The pressure relief valve located in the pump prevents the fluid pressure from exceeding the predetermined maximum pressure of the system. Flexible hoses carry the fluid to the control valve of the steering unit. The smallest or high-pressure hose carries the fluid to the control valve of the steering unit. The larger of the two hoses is the return, or low-pressure hose. A flow control valve is combined with the pressure relief valve located inside the pump.

When the fluid circulation reaches about 2 gals. per minute, the flow control valve is forced to open a passage between the inlet and outlet sides of the pump, and all excess oil is sent back to the intake side of the pump and recirculates through the pump. When oil pressure exceeds the fixed pressure limit, the relief valve opens and allows fluid to flow back to the inlet side and recirculate in the pump without raising the pressure in the rest of the system.

There are five types of pumps in use: vane, rotor, roller, sleeve, and slipper. Detailed information for the pump concerned can be found in the shop service manual of the particular car make and model.

Before any major service operations are started, the following items should be checked and corrected.

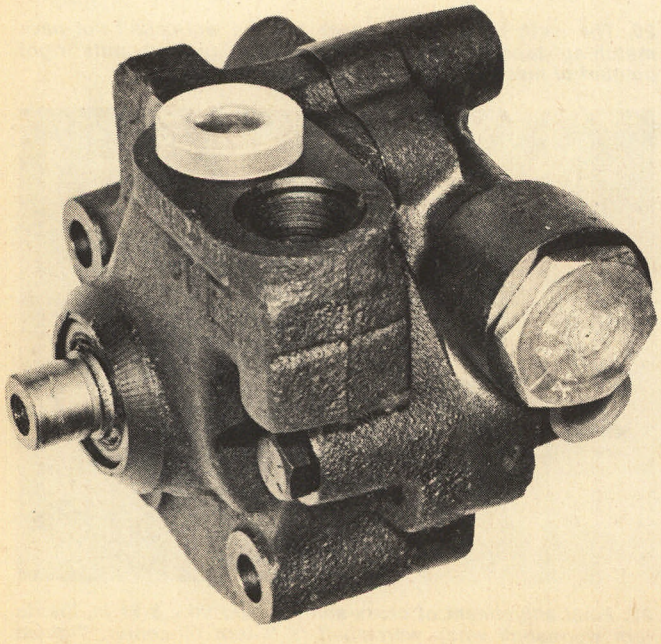
FLUID LEVEL

Check level at regular intervals. Wipe the cover before opening to prevent dirt getting into the system. If there is no other specific filling instruction indicated, maintain fluid level 1 in. below the top. If fluid is very low, check system for leaks. If only a small amount of fluid is needed, automatic transmission fluid can be used. When using larger amounts or changing fluid it is advisable to use special power steering fluid. Oil should be at operating temperature, wheels in a straight-ahead position, and the engine stopped when you check or add power steering fluid.

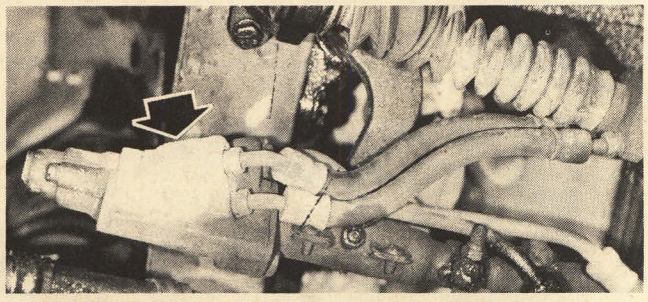
BELT TENSION

Belt tension should be maintained to factory specifications with a belt-tension gauge. The specifications vary, so you must check the specs in your manual. A belt that is too loose will result in reduced pump output, while one that is too tight will wear out the bearings in the pump. If you don't have a belt tension gauge, and can't get one, a good rule of thumb is to tighten the belt just to the point where it doesn't slip and squeal when the steering is turned to full lock. Don't ever try this with a worn-out belt, however. Such a belt would probably squeal at full lock no matter how tight it is. Be careful with your pry bar when tightening the belt. It is easy to damage the pump.

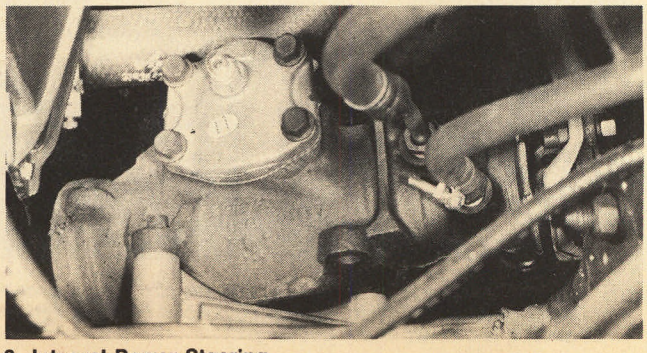
Check the belt for evidence of age



1. Eaton Power Steering Pump



2. Ford Linkage Power Steering



3. Integral Power Steering

and wear. Frayed edges, separation of the layers of the fabric (look at the side of the belt), and cracks on the inside of the belt indicate age and brittleness. The application of a good belt dressing will reduce slipping and noise.

POWER STEERING CHECKS

The steering gear, linkage, and front end should be serviced, lubricated, and alignment checked before any major work is attempted on the pump. Check tires for correct air pressure. Steering effort can be checked with a spring scale, with engine idling and front wheels on a smooth floor or driveway. Attach a spring scale to the rim of the steering wheel; as you turn the wheels from one extreme to the other, the pull should not exceed 10 lbs. at any point.

You can check the oil flow and relief valves by turning steering wheel full right or left, with the engine idling. If these valves are working, a slight buzzing noise can be heard. Caution: Do not hold the wheel in this extreme position for more than 2 or 3 secs. If the relief valve is not working, the high pressure might damage the system. If no buzzing noise can be heard, a sticking or malfunctioning valve should be suspected.

POWER STEERING REPAIR

Because the modern power steering unit is a precise piece of engineering, and due to the requirement of a number of special tools, we cannot recommend that the beginning mechanic tackle this job outside of a completely equipped shop with the help of qualified professionals. If any of the faults mentioned above occur and the indicated repair consists of more than linkage replacement, belt tightening, or the use of an additive, take the vehicle to a qualified professional. Do not attempt to do it yourself. On the other hand, if you've got a reasonably well equipped tool kit and some savvy accumulated by working under the hood of your car, there's no reason why you shouldn't be able to disassemble and clean your own pump and steering box, taking care of a leak or two in the process.

We've included a photo story on replacing the O-rings in a Chrysler power steering pump, a job that would be similar on most other make pumps, and one that the average weekend mechanic could tackle. Repairs beyond those on this level are probably best left to a qualified shop that has all the specialized tools and know-how.

1. Several American Motors cars use an Eaton pump. This is what it looks like with the reservoir, pulley, and brackets removed. It can be purchased in this form for about $65, which is more than a stiff jolt in the wallet.

2. Ford uses linkage-type power steering. The housing indicated by the arrow has several seals inside that are usually the cause of most leaks. The hoses all screw in and can be replaced easily.

3. Most makes (other than Ford) use a power steering unit that is built into the gearbox. The hoses connect directly to the box.

4. Before removing the power steering pump V-belt, detach all connections.

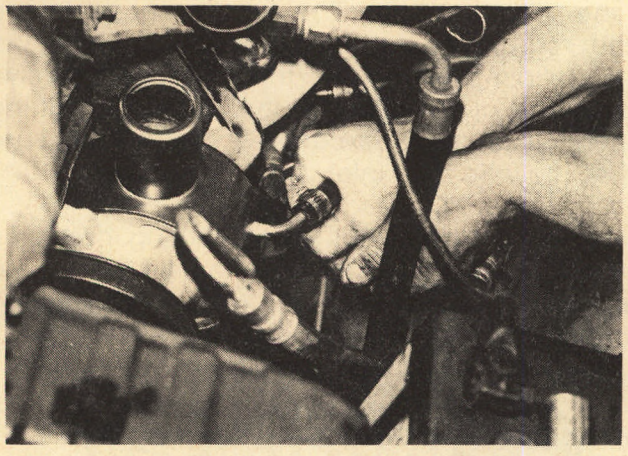
5. You'll need an open-end wrench for this one. When replacing the pump, be sure all fittings are on the snug side.

6. Loosen the pump bracket and slip the V-belt off the pulley. Some mechanics prefer to remove the bracket attached to the pump; others prefer to leave it in place, removing the pump only.

7. Place the pump against a solid object like this vise and break cover seal by tapping with a mallet.

8. With the pump secured in the vise, remove and replace the O-ring seal. If this doesn't stop a pump leak, you'll probably have to buy another unit for best results.

CHRYSLER PUMP O-RING REPLACEMENT



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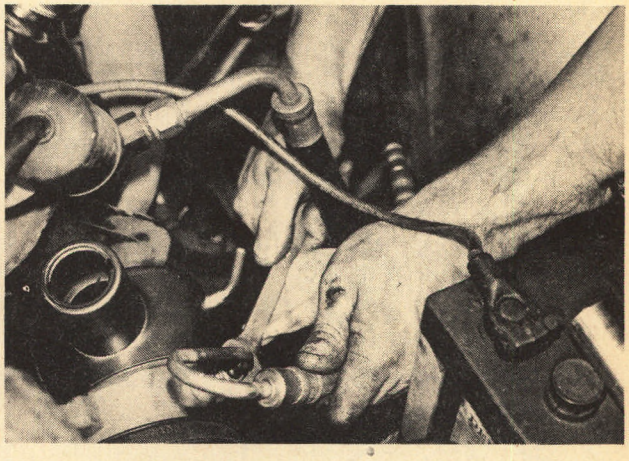

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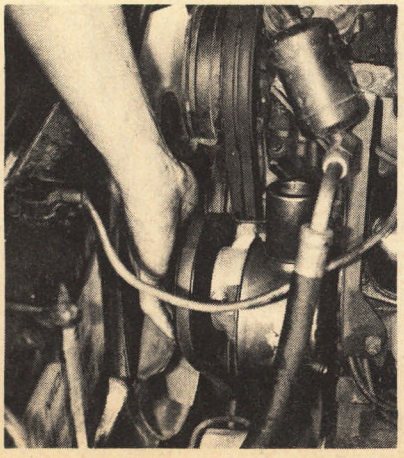

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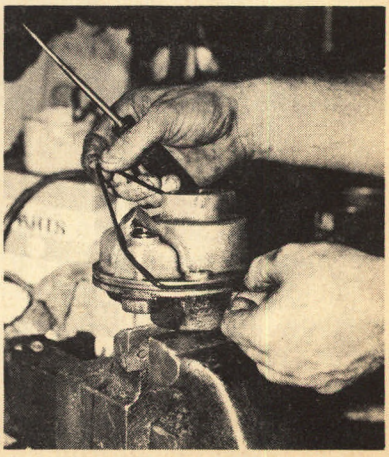

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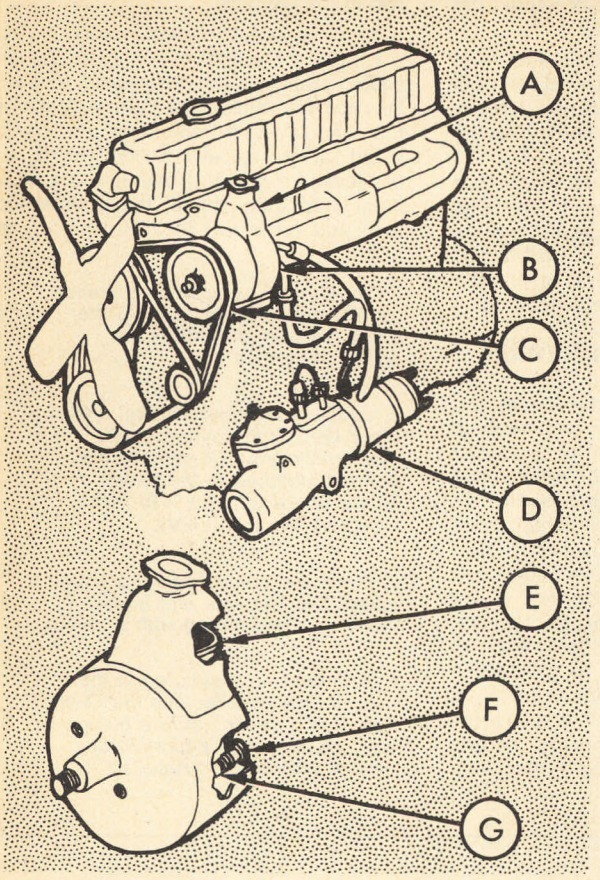
TROUBLESHOOTING POWER STEERING



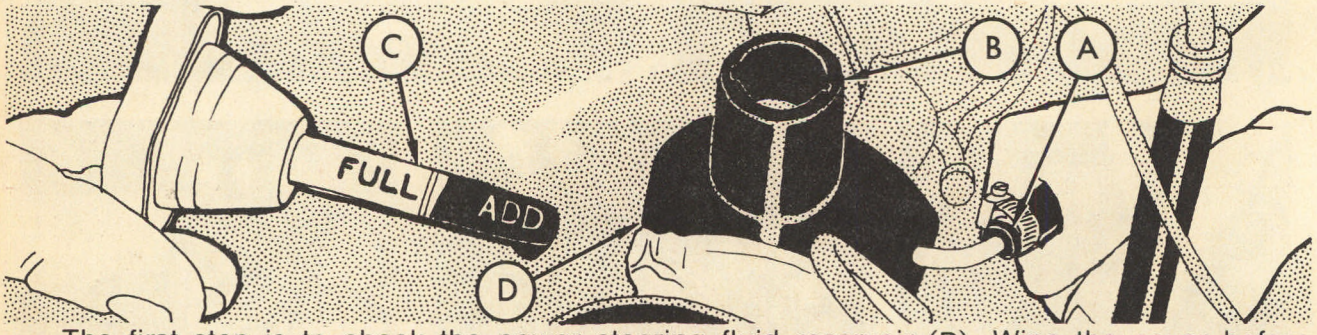
The power steering unit assists the driver by reducing the fatigue or strain of turning the steering wheel, especially at low speeds or in tight spaces where the requisite physical force may be quite high. The system consists of two basic units: the hydraulic fluid pump (A) and the steering unit (D). The power steering pump is driven by a belt (C) that may drive the air conditioning pump too. Power steering pumps usually deliver between 650 and 1,300 pounds pressure, depending on the design and type of the pump. The fluid used is a special fluid developed for this one use. In some cases, however, Type "A" automatic transmission fluid is used.

NOTE: CHECK THE SHOP MANUAL OR LOOK FOR A SERVICING TAG ON THE UNIT BEFORE ADDING FLUID. NEW FLUID SHOULD ALWAYS BE OF THE TYPE RECOMMENDED BY THE MANUFACTURER.

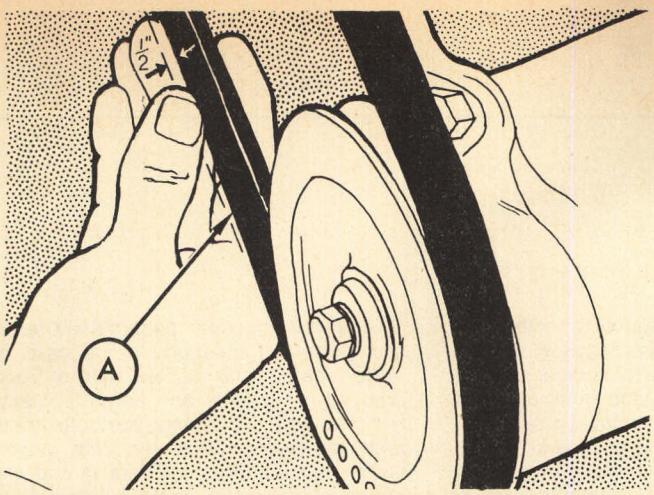
Part of the pump assembly is taken up by a reservoir (B), which holds fluid for the system. It also incorporates a filter screen (E) inside to remove unwanted particles and foreign matter from the fluid before it goes to the steering unit.

Hoses carry the fluid from the pump to the steering unit. The smaller hose is the high-pressure hose, while the larger hose is the return line for fluid coming back to the reservoir. When fluid circulation reaches about 2 gallons per minute, the flow control valve (F) opens to form a passageway between the inlet and outlet sides of the pump, permitting excess oil to recirculate through the pump. When oil pressure exceeds a pre-set pressure limit, a relief valve (G) opens and allows fluid to flow to the inlet side of the pump and recirculate without raising the pressure in the rest of the system.

In checking out a power steering unit, be sure that any steering or handling problems are not the fault of some other part of the front suspension or steering mechanism. Once that portion of the check is satisfied, you may then turn your attention to the power steering system itself. (See the chapters on suspension and brakes.)

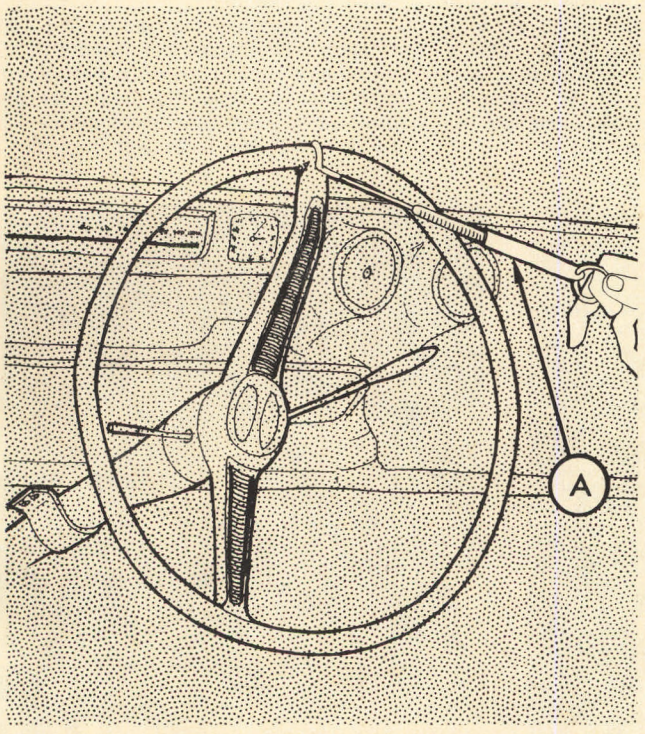


The first step is to check the power steering fluid reservoir (D). Wipe the cover before opening to prevent dirt from getting into the reservoir. Most power steering units have a small dipstick (C) built into the reservoir cap. The dipstick will show you the exact fluid level in the reservoir. If there is no specific filling level indicated on the pump or the dipstick is not legible, check the shop manual or maintain the level about 1 inch below the top of the filler opening (B). If the fluid level is very low, check the system carefully for leaks. Check all connections, hoses and joints for signs of fluid leaking out. Coverings on hoses (A) should not be frayed or cut. After you are satisfied that the system is not leaking, the next step is to check drive belt tension.



Examine the belt just as you did when checking the drive belt for the charging system (it may in fact be the same belt on some cars). Look for worn or frayed material or glazing of the sides of the belt which would indicate the belt is slipping into the drive pulleys. Belt tension (A) should be maintained at the factory recommended settings. If you can find a belt tension gauge, use it to set the tension. If not, set the belt tension just tight enough (approximately ½-inch deflection [A]) so that it doesn't slip when the steering wheel is turned all the way from side to side with the engine running.

WARNING: DO NOT REACH INTO THE ENGINE COMPARTMENT NEAR THE FAN BELTS AND PULLEYS WHEN THE ENGINE IS RUNNING. SERIOUS INJURY CAN RESULT FROM CLOTHING OR HANDS BEING CAUGHT IN MOVING PARTS.



The effort required to turn the steering wheel is a good indicator of the way the system is working. Park the car on a smooth surface (garage floor or smooth concrete driveway), place the emergency brake on and run the engine with the transmission in "N" or "P." Using a spring scale (A), find out how many pounds of pull it requires to turn the steering wheel.

NOTE: IT IS IMPORTANT THAT PROPER TIRE INFLATION PRESSURES BE MAINTAINED FOR THIS STEERING CHECK.

The usual reading for a good system will be in the range of 3½ to 12 pounds. In all cases, the effort required to turn the steering wheel should not exceed 20 pounds. A distributor point tension scale will work for this check. A scale of the type used for weighing game fish will do in a pinch.

You can check the fluid volume and pressure valves by turning the steering wheel full left and full right with the engine running. All other test conditions should be the same as in the previous check for steering force. If these valves are working normally, you should be able to hear a slight buzz as the wheels approach full deflection to one side. If no buzzing noise can be heard during the test, a sticking or otherwise malfunctioning valve should be suspected.

CAUTION: DO NOT HOLD THE STEERING WHEEL IN THE EXTREME RIGHT OR LEFT POSITION FOR MORE THAN A FEW SECONDS. IF EITHER OF THE RELIEF VALVES ARE NOT WORKING, THE HIGH PRESSURES BUILT UP MAY DAMAGE THE SYSTEM.

Because of its complexity, we do not recommend that the reader attempt to repair any part of the power steering other than adjusting the drive belt, tightening loose bolts and replacing hoses. If the troubleshooting procedure shows a possible problem, take the car to a qualified mechanic for repair.

Wheels & Tires

Tires, to put it very bluntly, are somewhat of a pain in the neck. It seems like they are always wearing out, going flat, or getting dirty, and no matter how well you take care of them, they never seem to look as good as they did the first day they were put on. You can wash them, scrub them, or paint them with tire paint that looks like something out of a tar pit, but they still never seem to regain the cool wet look of a brand new tire. We have been trying something recently that you may want to experiment with. We have found that spray can silicone will coat the tires with a moist film that does not soak in. But if you drive in dusty areas, you may have difficulty with it picking up a lot of dust.

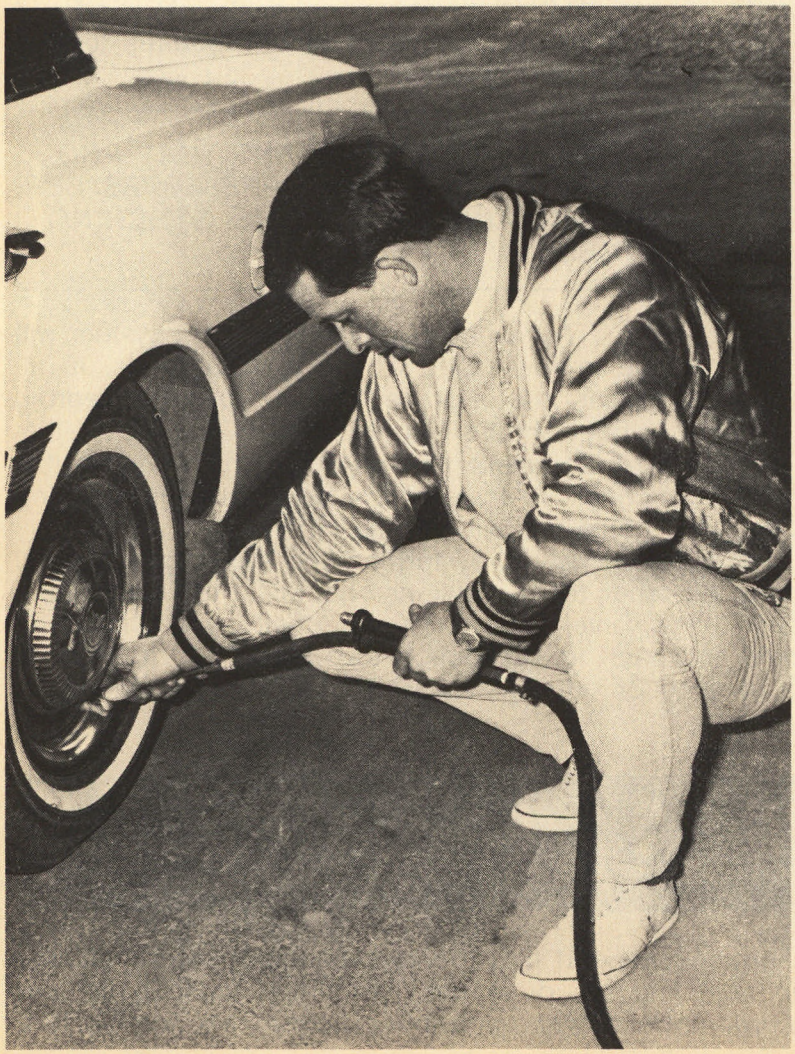
TIRE CARE

The most important as well as the easiest single step in tire care is maintaining proper inflation. Pressures specified by Detroit in owners' manuals, ranging usually from 24 to 28 psi for normal driving, tend to favor comfort and quiet over tire life. A trained, conscientious tire salesman will more likely recommend 30 psi at all 4 wheels for maximum tire life. A certain amount of air seepage is normal, which is why tire pressures should be checked at least once a month and before any long trip.

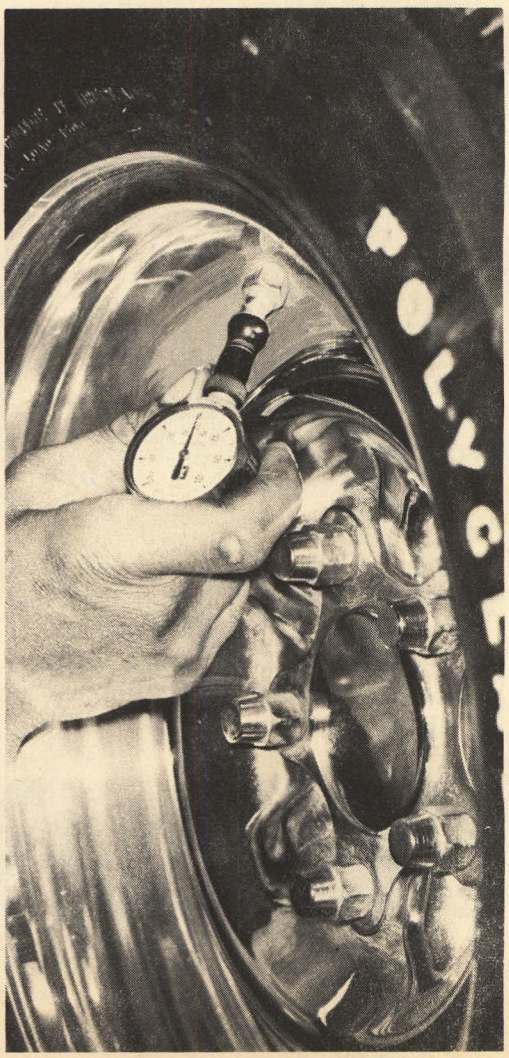
These figures are for a "cold" tire and take into account the normal pressure buildup from the heat generated by the car in motion. A 3-mile drive to the neighborhood service station is enough to raise a cold pressure of 30 psi to a "false" reading of 33 psi. A stop after a long hot turnpike run can result in normal readings of 36 to 40 psi. Under no circumstances should this seemingly excess pressure figure be bled off.

Characteristic wear patterns will result from incorrect inflation. In the case of underinflation the center of the tread area bows upwards and hardly contacts the road surface, causing the outer tread areas to wear excessively. With overinflation this pattern is reversed and the center of the tread wears out first. With proper inflation there is a certain normal irregularity in the wear between tread ribs but this occurs early and does not proportionately increase once established. Treadwear indicators that tell you when a normally worn tire should be replaced are now required in all tires installed on new cars.

There are recommended 5- and 4-tire rotation patterns and car makers do not agree as to which, if any, is best. Simple mathematics prove that if all five tires are rotated every 6000 miles the car can be driven 30,000 miles with each tire in



1. Checking Inflation Pressure



2. Tire Gauge

use for only 24,000 of this total. It also is likely that an unused spare will tend to deteriorate just sitting in the trunk.

On the other hand, you may have to rebalance after each rotation and the cost of this can at least equal the savings obtained from rotation. If it can be accomplished without rebalancing, 5-tire rotation at regular intervals will probably save you money. The problem is that while each tire and wheel may separately be in static and dynamic balance with its original brake drum (which rotates with it), changing the combinations can upset these happy relationships.

DETECTING TIRE DAMAGE

Tires should be inspected regularly for external evidence of cuts, cracking and separation of the rubber from the carcass. Small tread and sidewall cuts or cracks are of serious concern only when they penetrate far enough to expose the cord material. Assuming the cord is undamaged, exposure is not too much of a problem in a nylon or polyester tire, but rayon cord will absorb water and may be structurally weakened.

Irreparable damage will occur if the tire is run for any distance in a seriously underinflated or flat condition. This could be just that distance required to get from the fast lane to the emergency repair area of a freeway. Ply and tread separation can also be caused by underinflation, overload, or extreme speed—or combinations of these conditions. Tread separation will usually give a warning in the form of a loud slapping noise. In most cases the above types of failure will be covered under the tire builder's warranty which reimburses you for the unused mileage as gauged by tread depth remaining.

TIRE TROUBLESHOOTING

Tire problems caused by other than loss of pressure or chronic over- or underinflation can be due either to an inherent defect in the tire, or improper balancing. Tire problems could also indicate misaligned front wheels. Let's deal with the last item first as it is the most common and destructive.

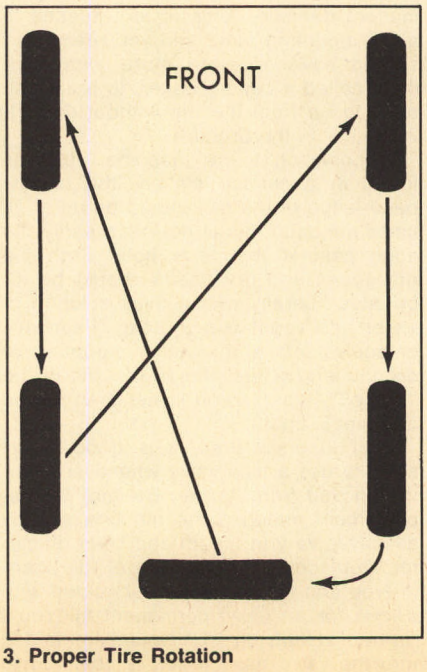
Improper caster or camber will cause premature wear on one side of each front tire. Camber is the measurement in degrees of the lean of the wheels. A wheel whose top leans in toward the car has negative camber. If the wheel leans out, it has positive camber. Caster is a measurement in degrees of the inclination of steering axis at each front wheel. Suspensions of modern design frequently use zero camber. In other words, the two front wheels run in positions very nearly vertical and parallel to each other. Toe-in and toe-out define another possible misalignment plane of the front wheels. If any of these adjustments are incorrect, tires may wear out twice as fast as the normal rate.

Another form of accelerated wear results from driver habits. Rapid front tire wear can be caused by habitual fast cornering. The correction for this is, of course, entirely up to you. If you mend your ways, a tire such as this can be restored to a normal wear pattern by moving it to one of the rear wheels.

The practice of "laying a patch" wears the rear tires excessively as can be imagined, but also unevenly for reasons that are not quite so apparent. Maximum acceleration actually bends the rear axle housings temporarily, causing the tires to wear faster on the inner edges. An identical wear pattern will also be observed in a car that is habitually operated with a maximum passenger and luggage load.

WHEEL BALANCING

Although it is not always necessary, tires may require two types of balancing. Static balancing is a procedure to correct a situation where a tire, wheeel, or brake drum—or a combination of these items—is "heavy" at a single point. Although this may amount to only an ounce or so, the effect is greatly magnified by centrifugal force when the wheel assembly is turning at speed. The symptom is a pronounced vibration in the vertical plane at any one or all of the wheels. You can feel it and also see it because the vibration is transmitted to the body structure nearby, such as the fender. Service stations and garages have machines, and hopefully personnel competent to operate them, that tell how heavy a corrective weight should be used and where it should be placed.



3. Proper Tire Rotation

Static balancing could probably best be described as a process by which a tire is put in balance so that there is no heavy spot anywhere that will force the tire to rotate when it is hanging free. For example, if a tire and wheel with a heavy spot is mounted on a precision spindle so that even the slightest amount of weight will rotate the tire until the weight is at the bottom, then we are checking static balance. The time-honored way of adjusting static balance is with the old-fashioned bubble balancer that enables the mechanic to get the tire in balance without spinning it. There are also machines that balance the tire on the car while it is spinning under power from an electric motor. Many people claim that such balancing, whether it is done by the operator's feeling for an unbalanced vibration or whether the imbalance is picked up by a stroboscopic light, is dynamic balancing. We feel that this is not dynamic balancing but merely a faster way to balance statically. When a tire is in dynamic balance, all of its weight is distributed equally from side to side so that there is no tendency for the tire to try to wobble as it rotates.

Suppose we had a tire that was 12 ft. wide, as an example. We could have a 100-lb. weight at one end of the tire and another 100-lb. weight at the other end. As long as the 100-lb. weights are diametrically opposite, the tire would be in perfect static balance and it would not have a heavy spot. But when you rotated this monster tire of ours, it would leap clear off the ground because when one 100-lb. weight is at the top of the tire, the other is at the bottom. One side of the tire is going to try to leap off the ground while the other side is trying to push itself into the pavement. You can see that the tire, although it is in static balance, is so far out of dynamic balance as to be useless.

Now, of course, our tires are not 12 ft. wide, but they are 4, or 6, or 8 ins. wide, and in that distance it is possible to have a heavy spot on one side of a tire so that it is in perfect balance statically but not dynamically. We feel that dynamic balancing can only be done on the type of machine that balances the wheel off the car while spinning it on a special arbor. Ordinarily this arbor is made to fit where the wheel bearings go into the drum so it balances the drum along with the wheel and tire. This is a convenient way of balancing, but it is not necessary to balance the drum because its diameter is too small to have much effect. The wheel and tire are the real culprits.

Now the question arises whether it makes any difference which way you have your tires balanced—on the car, or off the car. You can answer this yourself at a local garage after the tires are balanced, simply by having the car jacked up and the wheels spun in place. If spinning the wheels makes the car vibrate, then they are out of balance. It's as sim-

1. Even though some of the new "wide weenie"-type tires feature softer, less durable compounding, you can still squeeze their maximum mileage if you're conscientious about maintaining their factory-recommended inflation pressures. For maximum ride comfort, figure on about 24-28 psi max. For maximum life, gas mileage, bump pressure to 30-32 psi.

2. Tire pressure gauge is handy for those who keep after their tires' health, or for those whose car's suspension is drastically affected by incorrect tire inflation.

3. Tire rotation has been practiced for years in this "schematic" manner. The idea is to put an equal amount of wear on spare, thus prolonging the life of the other four. Chances are, though, you'll end up having to balance the spare and two rears.

ple as that. It doesn't make any difference whether you have them balanced on the car or off the car as long as they end up so that you can spin the wheels on the car without any vibration.

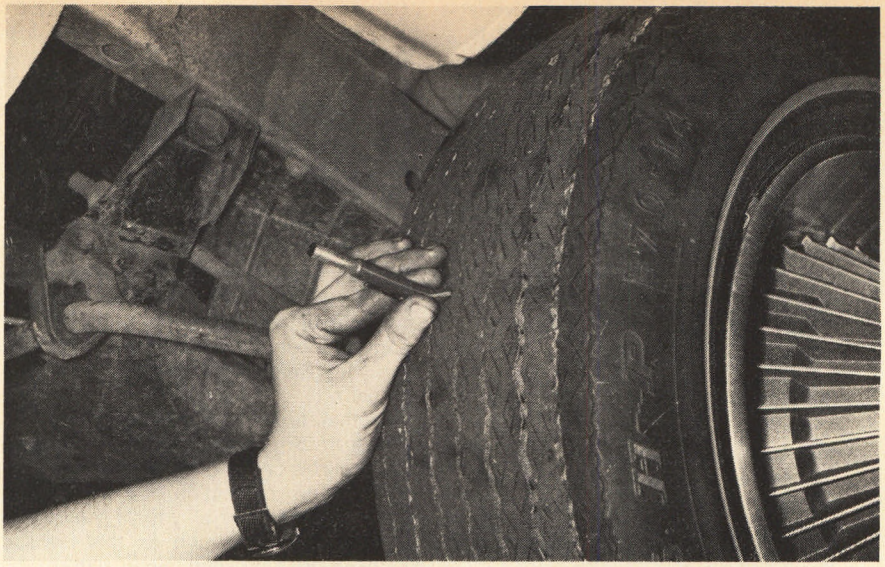
If the wheels do not vibrate when spun, but the car bounces all over the road when being driven, then there is nothing wrong with the wheel balance but you probably have a flat spot on a tire or an out-of-round wheel.

Checking tire and wheel radial and lateral runout is another method of determining if a chronic state of imbalance is caused by wheel damage, an improperly mounted tire, or a tire with manufacturing defects. To check radial runout of the tire, a dial indicator graduated to a thousandth of an inch is mounted on a convenient fixed surface and zeroed on the center rib of the tire. Rotate the assembly slowly. The combined runout of the wheel and tire should not exceed .050-in. Lateral runout of the assembly is checked by zeroing the dial indicator on the inside buff (curb protection) rib. It should not exceed .125-in.

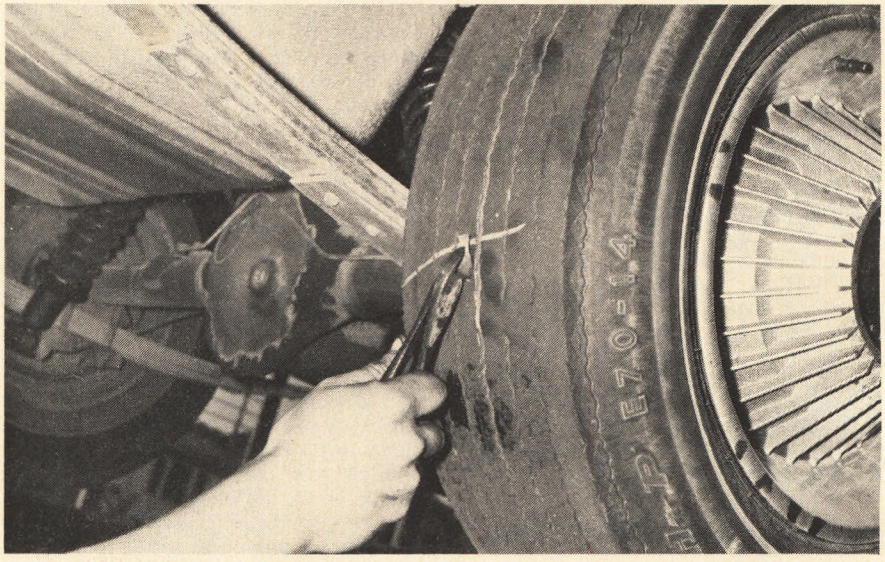
To find out whether it is the tire or wheel causing the problem, check the radial runout of the wheel. This should not exceed .035-in. If the wheel is true, the tire is at fault. But before condemning it, deflate and rotate the tire a quarter- or half-circumference and check for runout again. This will correct a possible misalignment incurred in mounting.

If both wheel and tire show runout, check to see if all of the lugbolts are properly seated. An improper torquing sequence (to be described later) can cause binding and poor seating of one or more lugs. A tire with excessive radial runout due to a defect in construction should be replaced or the tread may be ground down on a special machine to where it is even. This procedure is not used so much for correction (an out-of-round tire is covered by warranty) as it is to obtain a maximum degree of trueness for high-performance purposes. Excessive lateral runout is almost invariably caused by damage to the wheel itself.

A new Tire Problem Detector is now being used by some new car dealers. In use, the car's normal weight pushes the tire against a roller while it is rotated. At the same time a pen draws a "picture" of the tire's circumference on a piece of paper. If there are too many lumps, or the tire is out of round, it will show up in the drawing. Of course, this does nothing to fix the tire, but it allows the dealer to point an accusing finger at the tire manufacturer, who then has to give you another tire (you hope).



1. Tread Depth Gauge



2. Checking for Foreign Material

TUBELESS TIRE REPAIRS

The advent of the tubeless tire, standard on all U.S. passenger cars since 1955—combined with the so-called "safety rim"—has made it difficult for do-it-yourselfers because expensive special equipment is required. This is not just for convenience but to avoid damage to the tire when it is mounted or dismounted. A tubeless tire cannot be changed with the old-fashioned rubber mallet and hand iron without risking permanent damage. A basic tool needed is a tire mounting band and you really also should have an even more expensive item, called a bead breaker, to break the bead loose from the rim without damaging either in the process.

When using a tire machine, such as found in a service station, the narrow bead ledge of the rim should be up at all times although this is not necessarily the edge nearest the valve hole. Both the rim edges and tire beads should be lubricated liberally with a thick solution of water and vegetable oil soap (Palmolive or equivalent), and whether mounting or dismounting a tire, the beads should be "inched" into position rather than forced at a single spot.

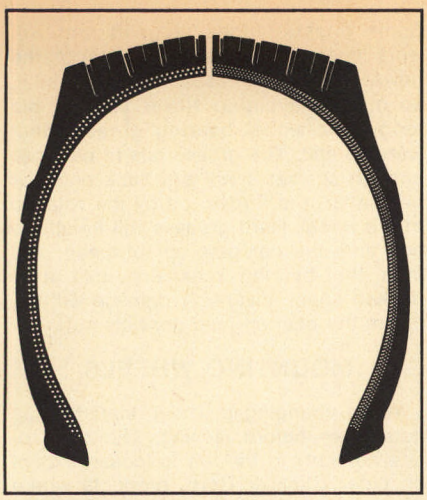
With tubeless tires, it is good insurance to use a new valve whenever a tire is removed from its rim. Be sure the replacement matches the old one exactly as valves vary in length and stem diameter. Replacement valves are of the snap-in type and have been prelubricated with silicon for an easy, permanent fit. You'll find an identifying "TR" number molded into the valve base which is common to

1. Tread depth indicators are useful for measuring how much rubber is left between the top of the tire and the bottom of the groove. Anything less than 1/16-in. means new hides.

2. The next time you've got your car up in the air, check the tires for any foreign material working its way into the surface. Make a chalk mark as a start/finish line, then eyeball the tire very carefully.

3. Two and 4-ply tires and cord angle are part of modern tire design. The more plies the greater inherent strength . . . but at the expense of heat buildup by the plies rubbing against themselves. Today's technology has improved the strength of the cord so much as to make good 2-plies the equivalent of 4-plies, 4-plies as strong as 8-plies. Cord angle (cords angle across the tire from bead-to-bead) on a standard passenger tire is about 35°.

4. Most tires are only statically balanced, that is on a "bubble" type balancer (lower photo). Lead weights are placed opposite heavy side of the tire/wheel. Dynamic balancing, where the wheel and tire are spun by a motor while on the car, is a bit more expensive, but more precise.



3. Two-, Four-ply Cross Section

all brands and is cross-indexed in the catalogs of the individual manufacturers for easy reference.

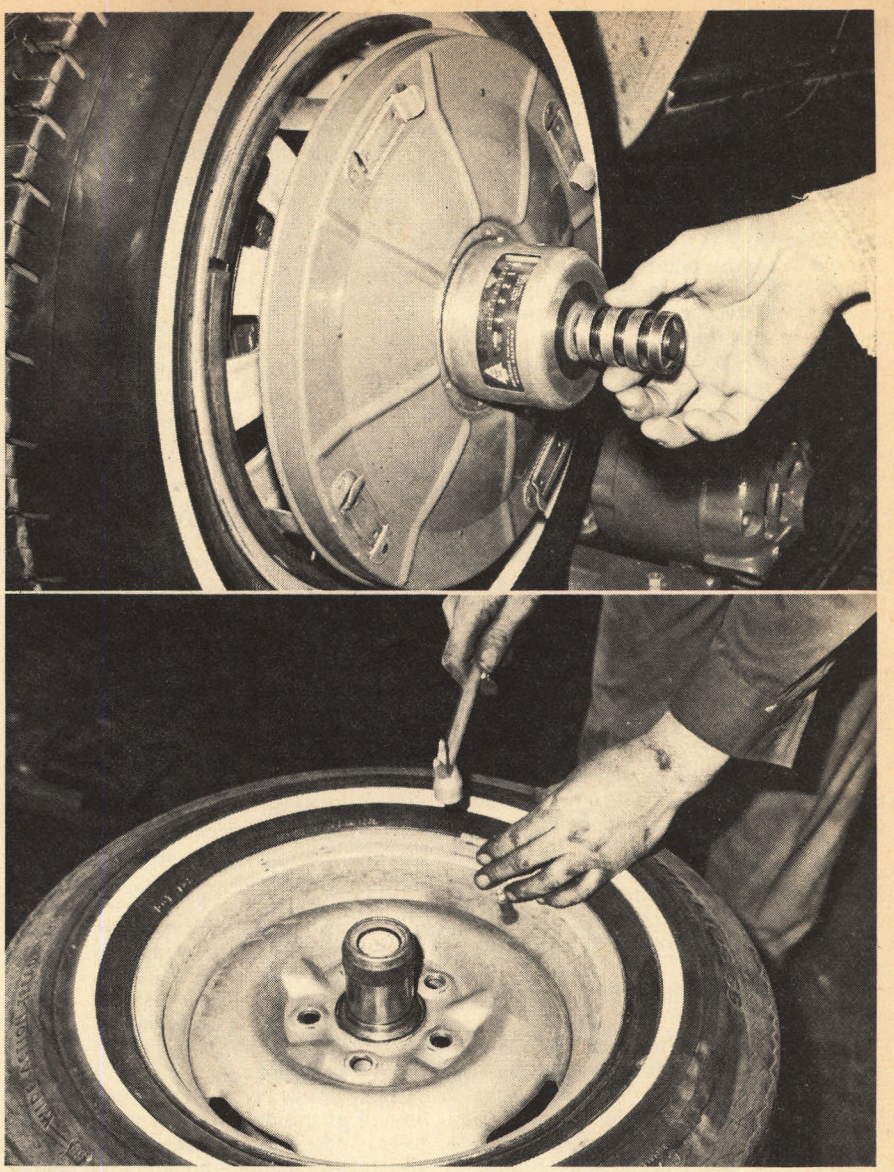
Caution: Temporary inflation pressures up to 40 psi—but no more—may be used to seat the beads on the rim. Many persons have been killed or seriously injured during this step in tire repairs. If the bead is not properly seated, pressures greater than 40 psi may cause it to break with explosive force. As a further safety measure, specialized tire shops use a clamp-on extension chuck on the air line to permit the operator to stand clear of the tire while inflating it.

Repairing small leaks in tubeless tires may be accomplished by any of four basic methods, and two of them do not require removing the tire from the rim or car. The first is to enlarge the puncture slightly if necessary, coat the hole with a suitable rubber cement and insert a rubber repair plug of the proper size. A repair of this nature should be looked upon as temporary.

The second and very recently developed method also uses a plug that may be applied with the tire on the car but it involves more permanency because the plug chemically vulcanizes itself to the tire. However, a $14 kit of special tools is required as well as compressed air to actuate the insertion gun.

Fully permanent repairs involve vulcanization with special dielectric patches applied inside the tire and special tools to supply current and pressure to the patch. This expense is practical only for those engaged in the tire repair business and, of course, the tire must be removed from the wheel to do the work.

Claimed to be permanent is an adaptation of the chemical vulcanizing procedure. After a certain amount of preparation, a special patch (Dill Sure-Cure or equivalent) may be applied much like a Band-Aid to the inside of either a tube-type or tubeless tire. The area around the cut or puncture must be buffed thoroughly with #3 sandpaper after first treating the area with a buffing solution (Dill B-4 or equivalent). The area is then treated with a self-curing vulcanizing fluid (Dill G-2 or equivalent) and the patch applied. The final step is to "stitch" around the edge of the patch with an inexpensive special tool (Dill Part No. 13 or equivalent). This looks and functions much like a cookie cutter except that it doesn't cut; it indents the patch to the surface for better adhesion. The above procedure, too, requires removal of the tire from the rim.



4. Dynamic and Static Balancing

The careless—and expensive to the consumer—practice of "repairing" a tubeless tire by merely installing an inner tube is to be avoided except in an emergency. Tubeless tires are of a different cross section than tires designed for tubes and a tube installed in them will very likely chafe and fail. As we mentioned, tubeless tires have been standard equipment on all U.S. cars and most imports since 1955, and the wheels provided by the car maker of necessity are air-tight. The only exceptions are wire wheels that had a spurt of popularity as a factory option in the mid-'50's (and are still offered on many of the sportier imports) and certain very early aftermarket "dress-up" wheels of the so-called "mag" variety. Tubeless tires may lose air if used on some early model cars because the rims were not designed to totally resist bead separation during severe cornering. Rare instances of a leak in a modern rim may be repaired by sealants available at specialized tire shops. It is not practical, however, to attempt to seal the many spoke sockets in a wire wheel.

INNER TUBE REPAIRS

A permanent repair to an inner tube is best accomplished by vulcanization with dielectric equipment similar to that described above. Even a replacement valve may be installed in this manner. It also should be remembered that if the damage involves the tire as well as the tube, the tire too should be patched. When installing a tube, both it and the tire should be lubricated with a soap solution. A tube-type tire should be inflated slowly while you hold the valve firmly against its hole in the rim. As a final step, deflate completely and reinflate to insure proper positioning of the tube within the tire.

ROLLER WHEEL BEARINGS

Since the advent of tapered roller bearings for front wheels, car makers now recommend that the bearings and spindle be lubricated only at the time of brake lining change or when the wheel and drum are removed for any reason.

The important points to remember in lubrication and assembly are that the inner bearing races are designed to creep

slightly around the spindle and therefore the latter should be smooth and lightly coated with lubricant to insure a slip fit. The second point is that the tapered bearings cannot function satisfactorily if any pressure is exerted upon them by the locking nut; yet, the locking nut must prevent excessive end-play.

Installation with a torque wrench is desirable, but if you don't have access to the tool or the torque figures specified by each car maker, the following procedure may be safely followed: Tighten the lock nut with an 8- or 10-in. wrench, using enough arm length leverage to ensure that all parts are properly seated while the wheel is spinning. Back off the lock nut finger-loose, then tighten finger-tight. If the hole in the spindle lines up with a slot in the nut install the cotter pin. If not, *back off* to the next slot and install the pin. Finally, clinch the cotter pin and cut off the excess length to ensure that the ends do not interfere with the dust cap or static collector. In some designs a tab-type lock washer is substituted, but the cotter pin is the most common type.

For lubrication, use nothing but an extreme pressure (EP), lithium-based grease compound made especially for this purpose. Special packing tools are available for greasing the bearings, but a suitable substitute is to put a quantity of grease in the palm of one hand and work it into the bearing with a rotating motion of the other hand. Prior to lubrication, all parts should be cleaned in kerosene.

If you have access to an air gun, then air pressure may be used to help clean out the old grease, if you do not spin the bearing. Never under any circumstances spin a bearing with air pressure or any other means. Not only is that hard on the bearings, but dangerous, because pieces could fly off the bearing and injure you. On top of that, spinning is completely unnecessary for proper cleaning.

New lubricant should not be added to the old, and whenever these parts are lubricated, a new oil seal should be installed. This seal can be seated by hammering gently on a block of wood placed on the seal.

On cars equipped with drum-type brakes, it may be necessary to loosen the brake adjustment before the wheel and drum can be removed as a unit. On cars with disc-type front brakes the caliper must be removed. The only caution to observe is to not let the caliper assembly dangle on its hoses. Hang it on the nearest convenient piece of steering linkage. On front-wheel-drive cars such as the Toronado and Eldorado the rear-wheel bearings may be removed, lubricated, and replaced in a manner quite similar to that described above.

BALL WHEEL BEARINGS

Procedures for removal and greasing of ball front wheel bearings are the same as for tapered rollers. However, the installation of the bearings is slightly different. Ball bearings must be installed with a slight preload so that the balls and races are brought into proper contact. All kinds of directions have been devised for adjusting ball front wheel bearings, most of them difficult to understand. Most castellated nuts have only six positions for the cotter key, so even after you get the nut exactly where you want it, you may have to turn it tighter or looser to insert the key.

The main thing to remember on ball front wheel bearings is that they must never be adjusted loose. This doesn't mean to put a 3-ft. breaker bar on the nut to tighten it. It does mean that you should have zero play, with a slight amount of preload.

Ball front wheel bearings were a great source of trouble on the cars that used them. Today all cars use tapered rollers, which have eliminated the front wheel bearing problems. There is no tapered roller that will interchange with the old ball bearings, but there is a trick that can be used to prolong their life.

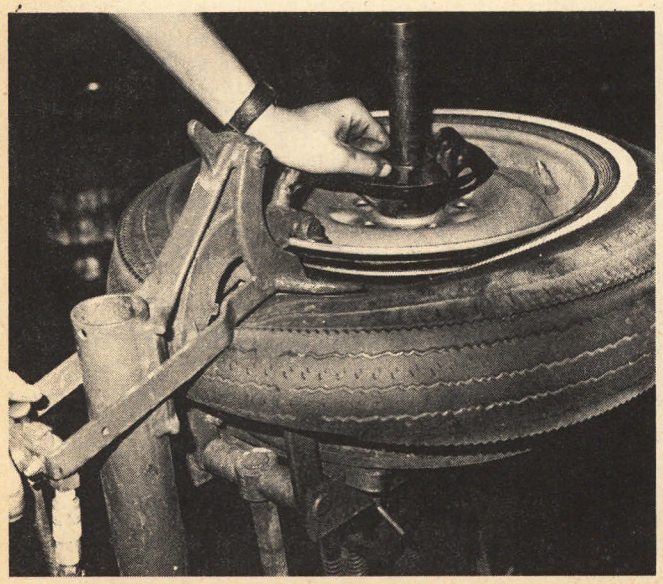
The secret is to use a grease in the wheel bearings that is almost runny. Some chassis lubes are soft and will work fine. If the grease is one of the newer "black" greases with moly in it, so much the better. Never use the old long fiber wheel bearing greases that were so stiff. The grease has to be loose enough so that it will run back onto the balls after it is thrown off by the rotation of the wheel. Hard greases will fly off the first time the car gets up to speed, and then the bearing runs dry until it is packed again. Invariably damage will occur to the bearing, and possibly hub.

MOUNTING WHEELS

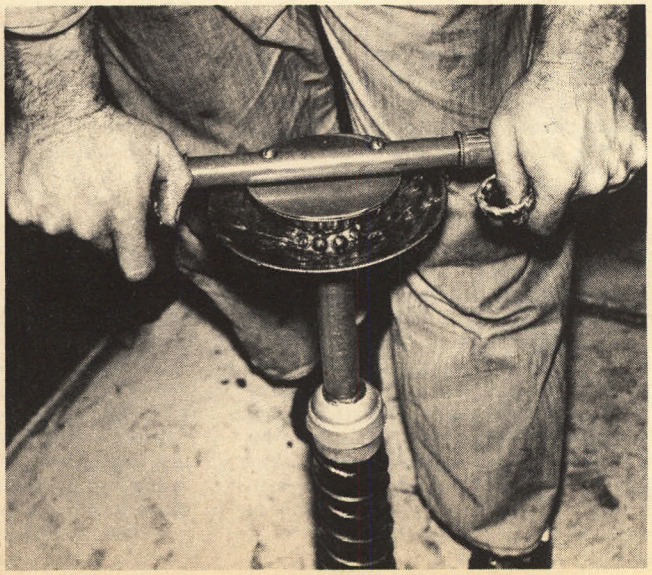
When changing a wheel, start the lug nuts loose before jacking. The nuts rotate normally to the left to loosen except on older Chrysler Corp. products where the nuts attaching the left wheels require right-hand rotation to loosen. When installing a wheel, first tighten the uppermost nut firmly but not securely and then tighten the one opposite on the bottom. Continue to tighten opposing pairs just enough so that the nuts are firmly seated. When all have been tightened, rotate the wheel and check for an out-of-round condition that means the nuts haven't seated properly. Then lower the car from the jack and final-tighten the nuts in the same sequence as above. Remember that after a 100 or so miles of driving, the nuts should be rechecked for tightness. Car makers specify torque figures (usually 70 ft.-lbs.) for the lug nuts, but the lug wrench provided with the car is of a size that makes it impossible for a person of normal strength to over-tighten wheel lug nuts.

1. This is the only practical way to separate today's tubeless tires from their rims without damage.

2. Wheel bearings should be greased every 12 months or 12,000 miles, whichever comes first. Garages use a tool which forces fresh grease into bearing. Most backyarders can do the same by cupping one's hand, filling depression with grease, squeezing grease through by sliding bearing across palm in a wiping motion.

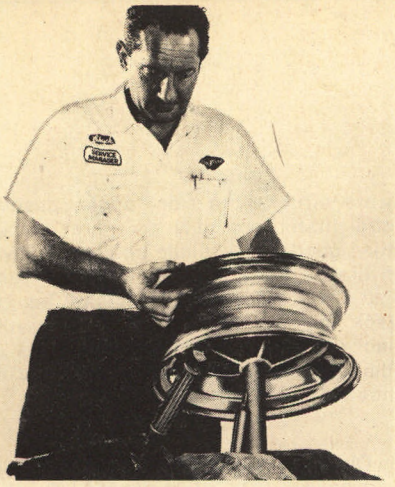


1. Removing Tubeless Tires from Rims

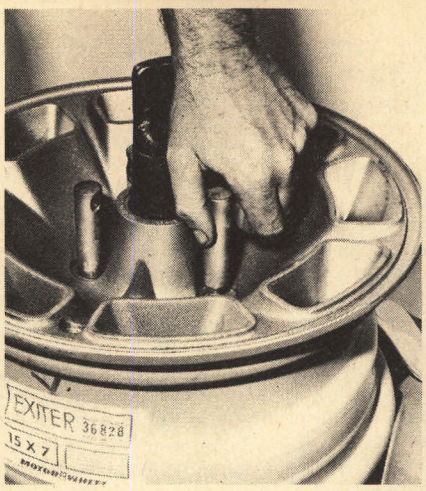


2. Wheel Bearing Packing

HOW-TO: Tire Mounting on Mag Wheels



1. Want to know right way to mount mag wheels? An expert at Motor Wheel Corp., Lansing, Mich. 48914, shows how without scratching the wheels.

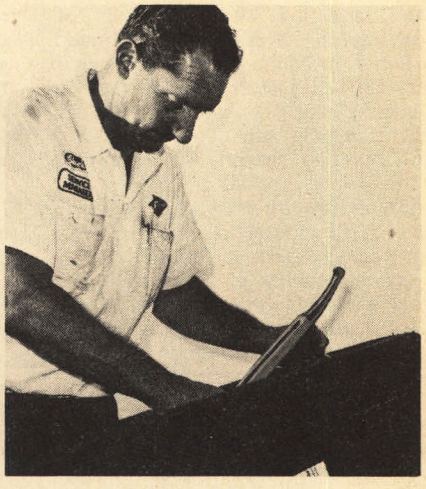


2. Drop wheel on changer, make sure flange is up. If rim is deep, mount face down to protect finish. Secure wheel by specific lug hole hold-down.

3. Many "mags" can be damaged when center-hold-down-method is used. Forget this technique if center can be damaged. Shop cloth protects finish.

4. Before putting valve stem through the stem hole, carefully inspect rim for leak-producing dirt, grit, etc., remove any labels, then clean 'em up.

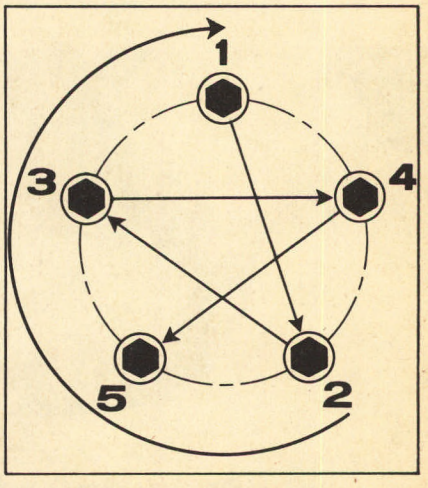
5. Before placing tire on wheel, lubricate both of the beads with household variety soap. It dries quickly, stickly, won't harm rubber rim.



6. Take time and watch out for the finish, start installing by working top bead over the rim. Once done the first bead should fall in center well.

7. Like top bead, the lower bead can be worked over wheel in a similar manner so it drops into center well. Work slowly, don't try to force bead.

8. After you've inserted valve core, air up tire to a maximum of 40 psi. If the beads aren't sealing properly use bead sealing band, relubricate tire.



9. When installing assembly on car, make sure stresses are equally divided and torqued to 80-90 ft.-lbs. Shown is recommended tightening sequence.

Body & Paint

Body and paint is a fascinating subject, with much more science to it than you would think from watching a body man swing his big hammer. Bodywork is fascinating because there aren't any two body men who would repair a car in the same way. It may be termed scientific because the body man who is fast can do the job in an incredibly short time, whereas another body man may take much longer and as a result be making a lot less money.

More than any other types of automotive repair, bodywork and painting should be carefully observed before they are attempted. Most body shops will welcome the amateur who wants to sit quietly by and watch how work is accomplished, and the body men will often pass along pointers as they proceed. The important thing to consider when watching a body man work is how he approaches each and every bent panel.

How a vehicle has been struck—that is, the point of impact—will determine how the repair should be made. This cannot be overemphasized. A really good body repair specialist may sit looking at a wrecked car for an hour before ever touching a panel. He is trying to determine exactly where the initial contact was (usually simple), the angle of the blow, severity, secondary impact points, etc. Once he has figured out exactly where the initial blow was, he may be able to save many hours of needless work.

If a fender has been struck head-on near the headlight, there will be damage far removed from that impact point. Chances are the fender will buckle at one or two places above the wheel opening, a slight buckle may appear in the large area behind the wheel opening, and the panel may have been shoved back against the door. This is where the unskilled workman can get into trouble very quickly.

If some kind of panel-pulling equipment is available, it will be possible to pull much of the damage from the fender without striking a hammer blow. However, if the point of initial contact is hammered out *first,* the remainder of the damage will be exceptionally difficult to remove.

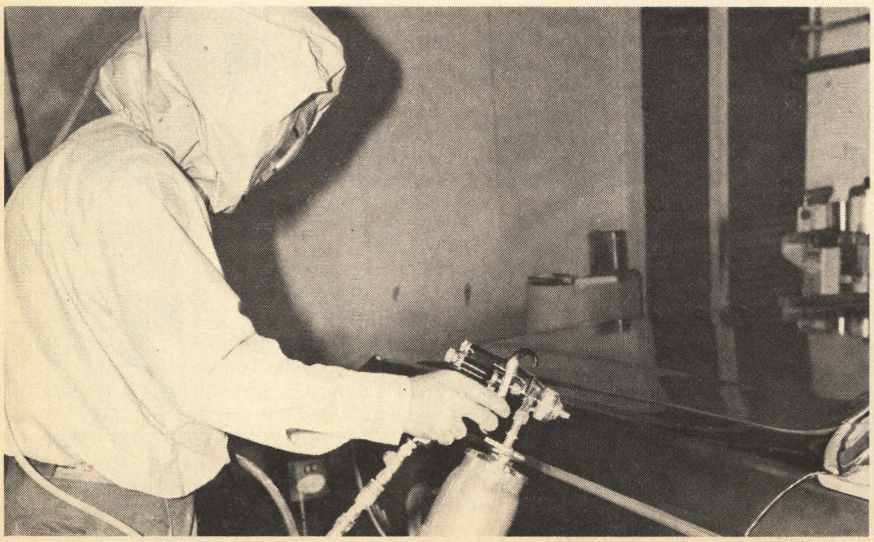
Again referring to the bent fender, if something can be hooked to the headlamp opening area and a pulling pressure exerted, the initial impact force is being reversed. The immediate crumpled area around the front of the fender will distort during this phase, but the force will tend to pull most of the buckles from the rest of the fender. This is imperative, and a part of almost every repair job.

Large body and fender shops will usually have a big pulling rig available. This is nothing more than a large I-beam that runs beneath the car and chains to the undamaged chassis in several points. The pulling apparatus is attached to the front and thus pulls against itself (the body attachments). Finding this kind of equipment for backyard repair is unlikely, so a push may be substituted for a pull. Body shops also have specially designed hydraulic jacks, usually referred to by the trade name of Porto-Power. With the bent fender, such a slim jack may be placed toward the rear of the fender on a strong frame point and the fender pushed back into rough shape. The jack is easier to use, but care must be taken to push the fender back in the same *direction of impact.* If the fender were struck at a front angle, pushing straight forward may do more damage than good. Work a little bit at a time with hydraulic jacks and you'll always come out OK. Of course, an ordinary bumper jack may be utilized where hydraulic jacks are unavailable. Which brings up the question of the tools that may be needed.

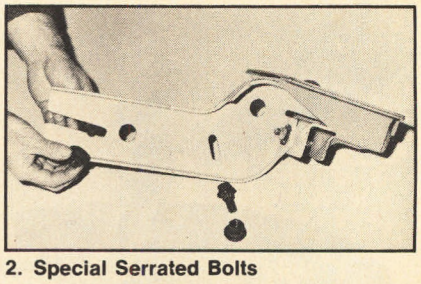
TOOLS

Obviously the amateur body man does not need a $1000 tool chest to fix up a dented fender, but there are several tools that are prerequisite. At the same time, many of the specialized body tools will find constant use in all aspects of automotive repair, and should therefore be considered as desirable. Following is a list of tools common to bodywork. An asterisk denotes those tools absolutely essential to the simplest repair job.

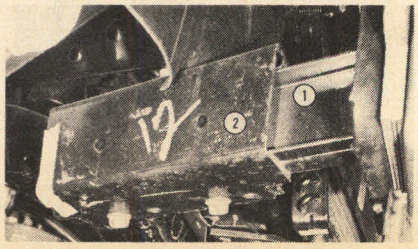
Wedge dolly
Combination spoon/dolly
Toe dolly
Anvil dolly (or "railroad" dolly)
*Tear drop dolly
*Scratch awl or ice pick
*File holder (adjustable type)
*Cheese grater (for epoxy fillers)
*Single-blade spoon
Double-blade spoon
Cross-mill shrinking hammer
Double-end flat face hammer
*Pick hammer
*2-lb. sledge hammer
Vise grips (pliers)
Large water pump pliers
*Pry bar
*Hacksaw
*Tin snips
Hydraulic jack
*Electric drill



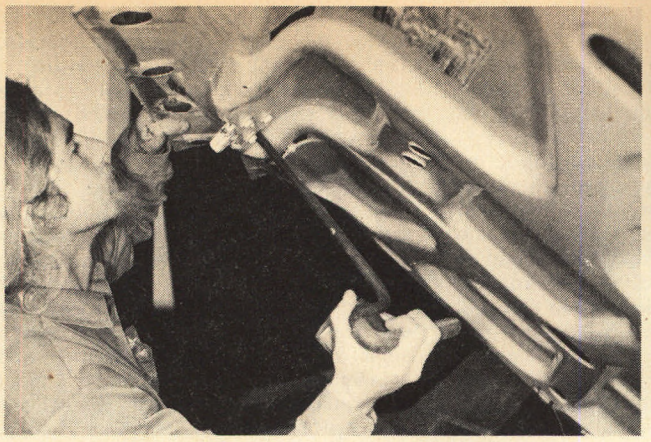
1. Spray Paint Hood Mask



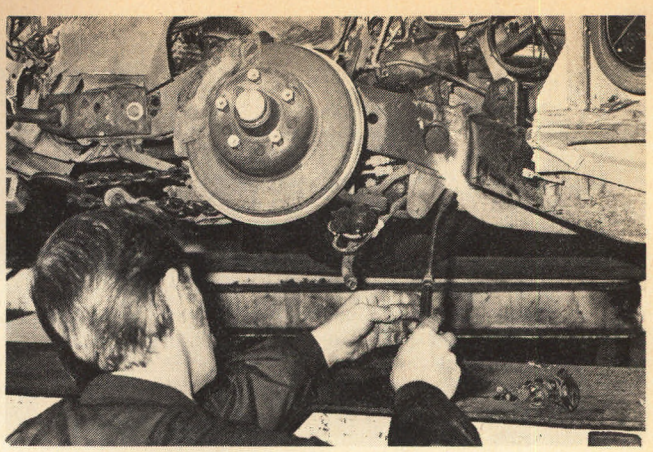
2. Special Serrated Bolts



3. Ford Shock-Absorbing Bumper



4. Straightening a Deck Lid



5. Frame Straightening

1. Newest wrinkle in painting—a hood mask with filter that inflates with air from the air pressure line and dispels toxic fumes from use of new enamel hardener additives.

2. Special bolts attach the Pontiac telescoping box sections to the frame. The bolts "crush" part of the frame and box into each other and have to be torqued to 80-100 ft.-lbs.!

3. Front bumpers on all 1973 cars use an impact-absorbing device to withstand up to 5-mph impact without damage. In the Ford bumper attachment device, an I-beam (1) rides inside a channel (2) and the two are bonded together with a special rubber that returns the I-beam to its original position after impact.

4. Picks in varying lengths, shapes and points are often used in places such as this deck lid where you can't reach the damaged area with a hammer to raise low spots.

5. Major collision repair, such as frame straightening, is best left to a professional with the proper equipment. Here a frame is being heated and pulled into shape on an alignment rack with the use of big chains and "come-along" pullers.

In addition to these tools, you may rent or borrow a welding outfit, disc sander, and paint spraying equipment. Such normally expensive equipment as this is a superb investment, but it is always possible to purchase equipment second-hand and save at least 50%. A good place to start looking for used hand and power equipment is the local body shop.

While the welding outfit is nice to have, you can repair the panel until welding is necessary, and farm the job out, then continue the repair. A disc sander is primarily a time saver, and the apprentice body man invariably finds he will learn the trade better if he concentrates on use of jack, hammer and dolly at first, doing all the finish work with a file. Lots of elbow grease is required with this type finishing, but an excellent job is easier to accomplish.

WELDING

Simple welding is an absolute requirement for any accomplished body repair man, although many repairs require little more than simple brazing. Because it is such an integral part of any body job, and actually attendant to most home vehicle repairs, the amateur should spend time becoming proficient with a torch. The best place for the young repairman to learn is high school or college auto shop, but an excellent alternative is the local garage.

Although they may seem rudimentary, there are certain precautions to observe when working with a gas welding outfit. First, always have a small fire extinguisher handy. There are many parts of a car that like to burn, and sparks from panel cutting or welding can get into the strangest places. Small extinguishers are available at low cost, but if nothing better is at hand, keep a water hose nearby. And never forget that a spark can smolder for hours in insulation before breaking out in flames.

Care and use of a welding outfit is explained in booklets available through parts and welding supply stores. They're mighty handy reading. They'll advise always mounting the welding bottles to a cart or chaining them to a work bench. A bottle can tip over and break off the regulator. When that happens either the bottle wants to go into orbit, or acetylene may catch fire. Either way, things get too exciting. Keep the hose connections tight, and turn off the acetylene and oxygen at the bottles after use.

One of the most common mistakes the amateur body man makes when welding is using the wrong torch tip. Because the sheetmetal is usually between 16 and 20 gauge, which means it is thin, a small tip is best (tip size designations vary with manufacturer). A large tip may work, but the heat generated will be transferred to the surrounding metal, causing warpage.

Different pressures are required for welding and cutting different thicknesses of metal. For sheetmetal welding, set the regulators at about 5 psi for acetylene and 10 psi for oxygen. For cutting the same thin sheetmetal, raise oxygen pressure to near 15 psi, and keep the acetylene at or lower than 5 psi. For ordinary work these same pressures will hold, but may have to be raised slightly when cutting frame members or very heavy steel. In no case should the acetylene pressure be above 15 lbs. since acetylene is dissolved in acetone. Too much pressure will cause the acetone to collect in the hoses and create a very dangerous situation. Normal hoses used for welding should never get more than 30 lbs. of oxygen pressure, and this high setting is used for cutting only.

After the regulator pressures have been set, which determines just how intense or harsh the flame will be, the torch oxygen valve should be opened approximately ⅛-turn and the acetylene valve approximately ½-turn. After the torch is lit, the acetylene valve should be opened until the flame begins to leave the end of the torch tip ("blows" away from the tip). Back the acetylene valve down slightly until the flame just touches the torch tip again. When first lit, the flame is a carbonizing type.

Gradually opening the oxygen valve will make the acetylene "feather" disappear and will produce a neutral flame. For body and fender repair, as well as most general welding, this neutral flame is desirable. To get the neutral flame, the oxygen valve is turned until the feather has been eliminated, and there is just a single small blue flame in the cone. Opening the oxygen valve further will make the flame hotter (known as an oxidizing type).

The intensity or harshness of a flame increases as the gas pressures increase. A flame which is too harsh may agitate the weld puddle violently, making good welding very difficult. A flame that is too soft may not have enough "push" to set the puddle for a good job. After becoming proficient with a welding torch, the body man learns many variations in the use of a single tip.

When welding body sheetmetal, the amateur will do best to tack-weld the separation in several places, making sure each surface is level at the separation. If one surface is lower, the final smoothing process is far more difficult. Keep in mind that metal will tend to "grow" as it is heated. Therefore, if a split in the fender is to be butt-welded, there should be a slight gap between the pieces. If the pieces touch, the welding heat will tend to create a small ridge down the weld, a ridge that must be heated and shrunk out.

When welding sheetmetal it is best to weld forward, ahead of the tip, rather than behind the tip. When welding backward, or moving along with the tip pointing back toward the already welded seam, the heat is increased in the panel, encouraging excessive warpage. When tilting the torch tip at a 45° angle and

pointing it ahead of the weld, it tends to preheat the metal and make a smooth bead every time. The welding rod is held at 90° to the flame, or 45° from the seam in the leading direction, and the flame is played in a small arc (usually about ¼-in. diameter) as the seam proceeds. A good weld will have consistent ripples throughout.

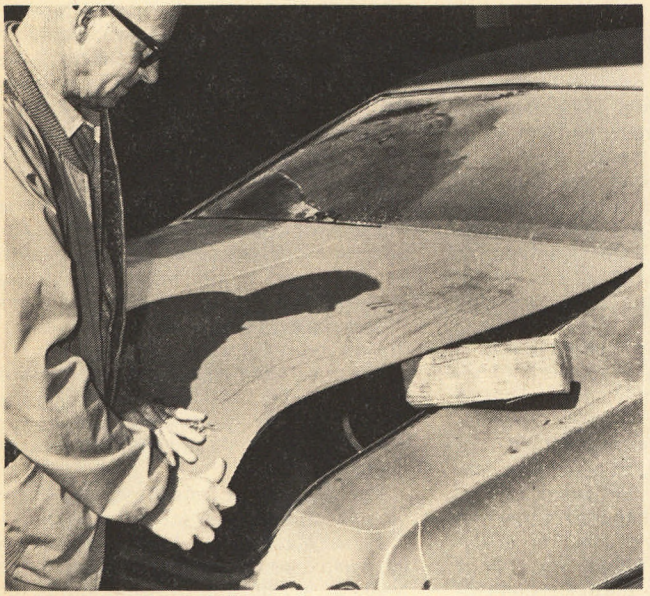
To weld a break or tear near the edge of a panel (around the flange, etc., which is a common occurrence), first rough out the panel to its approximate shape with a hammer and dolly. If there is considerable stress at that particular point, a jack may be necessary to get reasonable alignment. Clamp the edge of the split panel with flange pliers or vise-grips and tack-weld the break every inch or so. This will keep the edges from creeping during the final welding stage. Start the final weld bead at the apex of the break, working steadily toward the edge.

If a small section, or panel, is to be welded into an existing panel, such as the front section of a straight fender to replace the crumpled part of a fender, the entire cut must be tack-welded as mentioned.

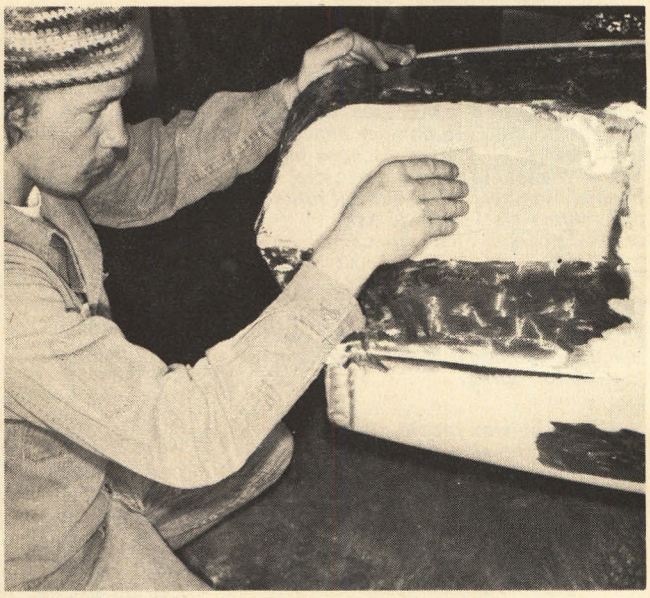
Hammer welding is not common to ordinary bodywork, being more attuned to customizing, but it can save time and effort of leading or epoxy filling. As the weld progresses, working with about ½-in. at a time, the weld is hammered flat with a hammer and dolly while still red. This flattens the entire welded seam and makes working with a pick hammer and file easy. Remember to wear a long glove on the dolly hand, and immerse the dolly in water regularly to remove heat buildup. Since this type of weld requires intermittent use of the torch, it is wise to build some kind of torch holder. In this way the torch will not have to be relit every 3 or 4 mins.

Brazing is simpler to master than welding, and some of the new low-temperature brazing rods are ideal for bodywork. However, the beginner will never know if he is doing a good brazing job or not unless he learns fusion welding also. There are many places where brazing is better than welding, particularly because of the low temperatures involved. At the same time, brass may be filed and ground smooth much as lead, so it is ideal as filler for small holes, etc.

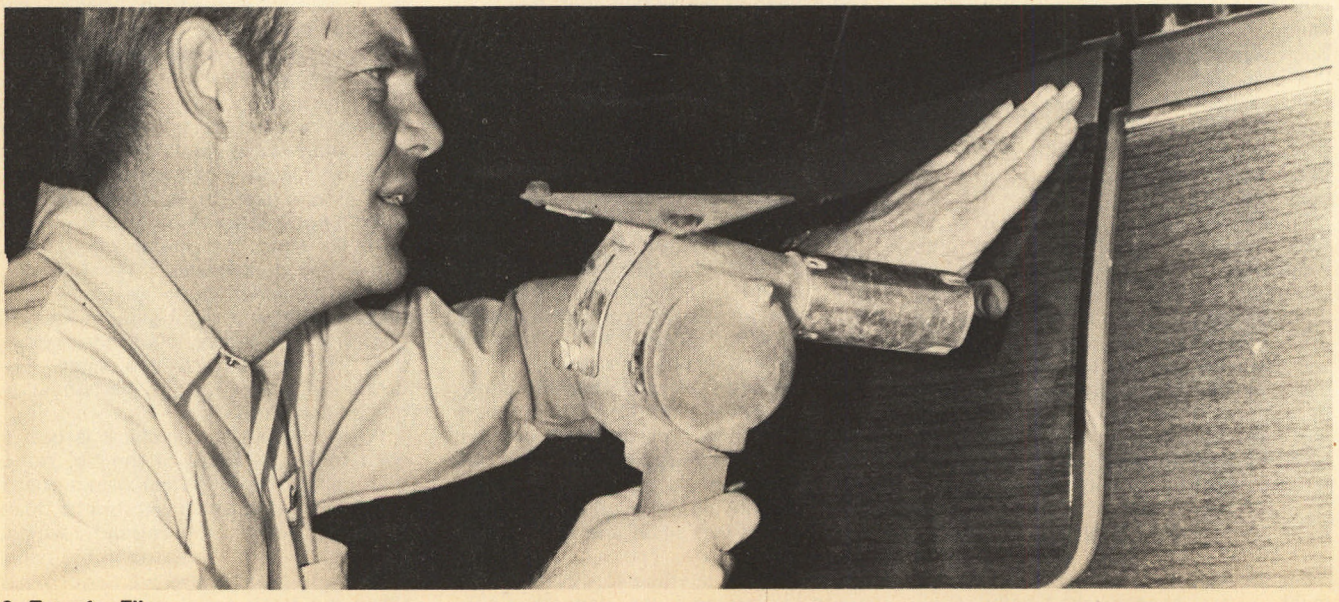
Use of the cutting tip is abused by many amateur welders, simply because they have not considered the problems involved. In bodywork, the majority of cutting will be done on large sheetmetal panels. Because the metal is so thin, a small cutting tip should be selected, and seldom can a gas cut be made without some minor metal warpage immediately adjacent to the cut. For this reason, when a panel is being replaced, always make the initial gas cut 2 ins. from the final cut, then sever the remaining piece with snips or a power shear. Power shears are available that work off ordinary drill motors. As soon as the metal is ready to cut, tilt the cutting tip in the direction of the cut and move briskly. This procedure will cut sheetmetal with a



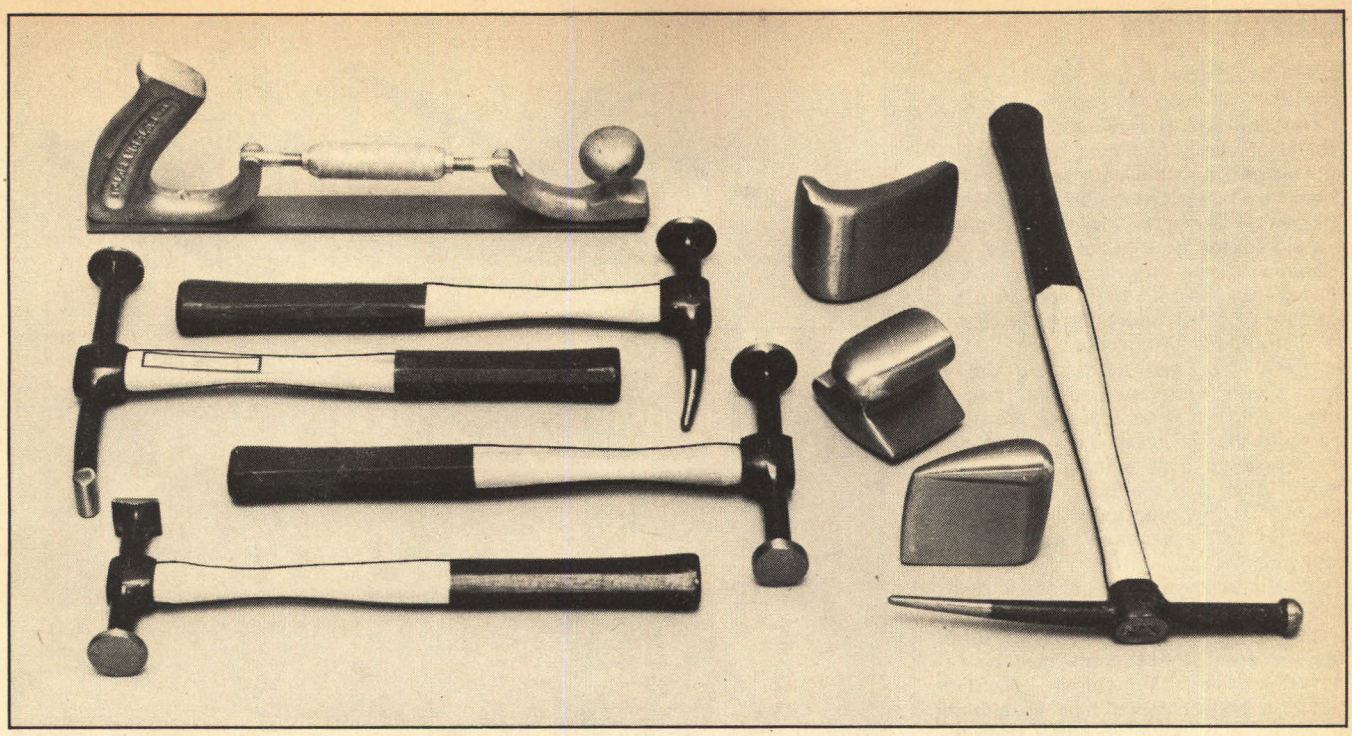
1. Aligning a Trunk Lid



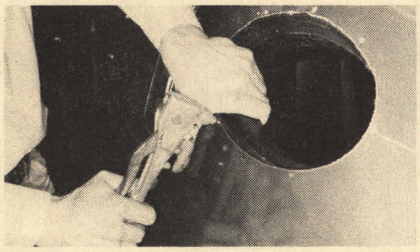
2. Using Body Filler



3. Transfer Film



4. Hammers and Dollies



5. Pop Riveting

1. Sometimes a small job of panel alignment on hood, doors or trunk lid can be handled simply, without special tools or training.

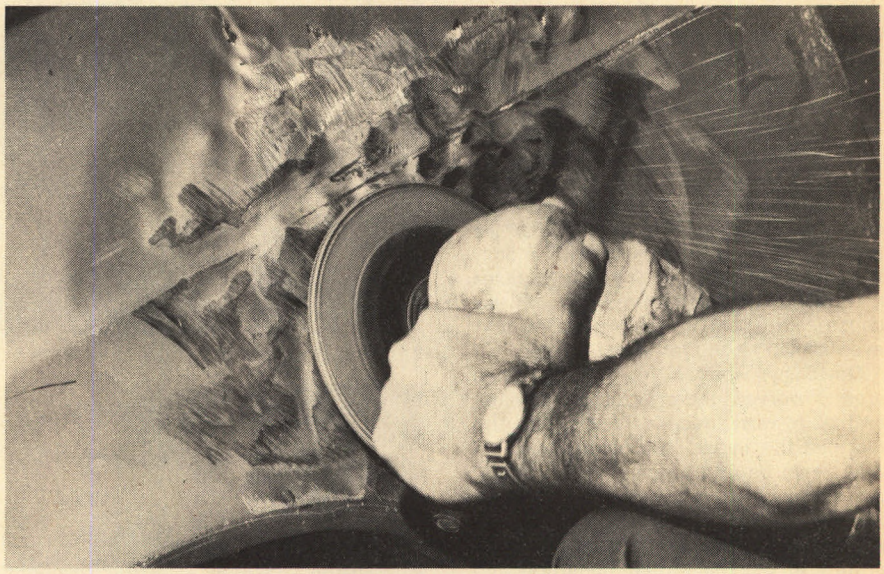
2. There are two basic ways to fix minor collision damage. The quick and easy route is lots of filler.

3. Simulated wood grain on transfer film is today's counterpart of the wooden-bodied station wagon. Material comes in rolls, is cut to fit desired panel, and is adhesive-backed. Here a door panel is being replaced. Film backing is peeled off, then film is placed over panel wiped with detergent. Heater speeds drying process.

4. The professional must have a variety of hammers and dollies for his work, but you may find objects around your garage to do the job.

5. Blind pop rivet gun is greatest invention since the welding torch, but a heck of a lot less troublesome. Special rivet is inserted in gun chuck, shank inserted in proper diameter hole drilled in pieces to be joined, then handle squeezed. In one operation rivet is flared on back side, excess rivet shank cut off.

6. The best repairs take more time, of course. A good metalman will get the panel as straight as possible first, so that only a thin coat of filler is needed. After preliminary hammering on the dent, grinding the surface shows high and low spots that have to be worked on.



6. Working the Metal

minimum of warpage, but does not work well with heavier steel.

WORKING METAL

As we have pointed out, when straightening a bent panel, the work should start in reverse order from impact. When the pressure that causes subsequent wrinkles and buckled areas down a panel has been released (by pulling or pushing into rough shape), start at the ridge farthest away from the impact point and start working back. In many cases, the minute this last ridge is straightened, most of the other buckles will disappear also.

Take that hypothetical fender again. The front of the fender around the headlight is crushed and wrinkled, but farther aft there is a depression above the wheel opening and a ridge behind that. By placing a spoon on the rear ridge and slapping it with a mallet or hammer, the ridge will be driven inward and the depression will spring outward to near original contour. Localized stress points have been relieved, leaving only small areas to reshape with hammer and dolly.

The secret to good bodywork is to use the hammer sparingly. If a panel is repeatedly hit with a hammer and there is no support behind the panel, a series of individual valleys is created. On the other hand, if the panel is supported by a dolly and is repeatedly struck, the metal is stretched out of shape. The best procedure is to select a dolly with the same general contour as the original panel line, then slap the panel with medium hammer effort, moving the dolly around beneath all the high spots. When visiting a body shop, note how the accomplished body man strikes a panel with about 60 blows a minute, making a kind of glancing strike on the panel.

To raise a low spot in the metal, place the dolly at the apex of the dimple and

strike the dimple edges with the hammer. This will raise the section. The kind of hammer used is very important. In the first place, body hammers are relatively light-weight, and they all have specially contoured faces. Using something like a ball-peen hammer to straighten a panel is the quickest route to the junkyard.

Spoons come in various sizes and shapes, but are primarily used on a big expanse of metal where the blow should be distributed over a wide area. They can also be used as backup dollies when space is cramped. Dollies vary in weight, shape and contour, but are nothing more than a hand-held anvil. Watch a professional body man and note how he will often use the dolly to tap up a low spot as he progresses, rather than resort to using a heavy and unwieldy body hammer.

Sometimes there will be small dents that are not easy to remove with a dolly, or perhaps a dolly cannot be squeezed into the area. These dents may be removed with a pick hammer. The pick end of a body hammer may be straight or slightly curved, but in either case the pick tip is rounded, not sharpened. When metal is tapped, the small rounded end will tend to stretch a tiny area, or cause little bubbles to raise. By striking metal from the underside with the pick, and placing a lightweight dolly on the outside panel surface, an area may be raised enough for final working. *Warning:* Never pick up a depression, such as a small dent that has been obviously stretched, and then grind or file the surface without working with a dolly in the normal manner. The little bubbles may be too high and when ground will cause thin spots in the metal, or may even allow the grinder to cut holes.

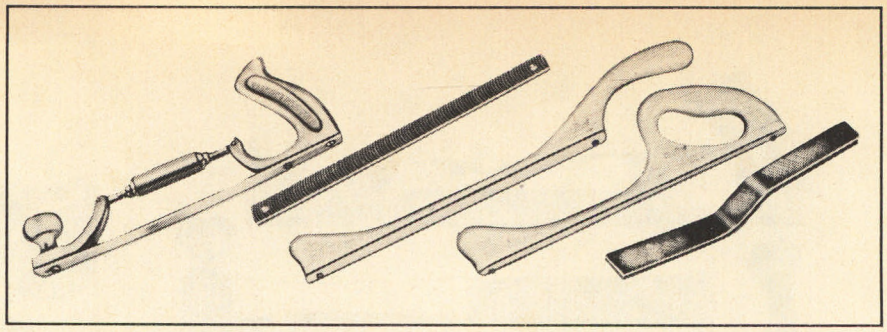
Obviously, when a severely crunched area is worked, there is lots of hammer and dolly work necessary. Despite the fact that this initial work might make the area seem beyond repair, you'll find that perseverance will prove the metal forgiving. As with that fender again, keep at it with light strokes and move the dolly around to get the proper contours—and soon the right shape will develop.

After the general contours have been reached, run the flattened hand over the surface. Any irregularities will be felt immediately and may be worked up slowly. Finally, file the area with a body file, holding the file flat and making even strokes. Remember that most automotive body panels have at least a simple curve, so do not file in one place long enough to cause a flat spot.

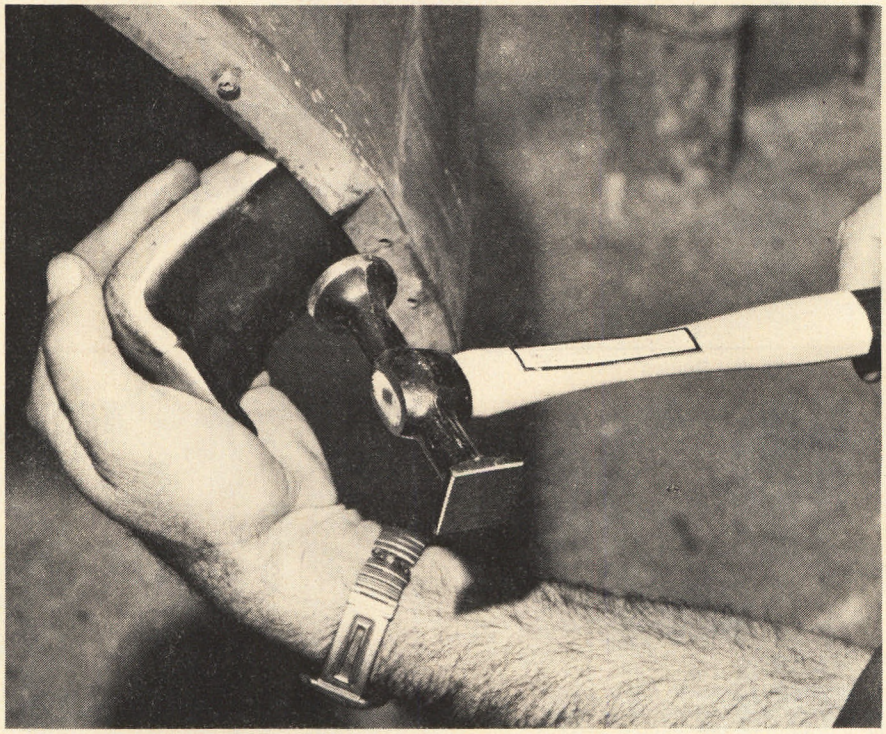
As the body file is shoved across the surface, it will take slight cuts off the high spots and leave the low spots untouched. Raise the low spots with the hammer and dolly, and continue until all the area is being filed with every stroke. A disc sander is faster, but the amateur will find the file gives a better result.

SHRINKING

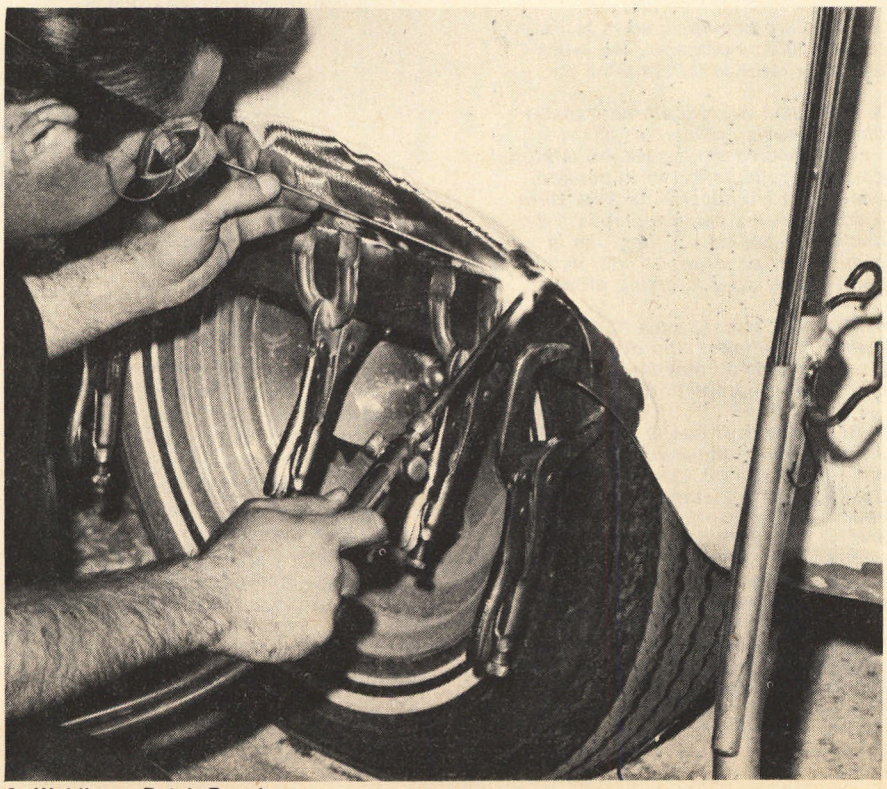
Any crease type of damage will probably require metal shrinking for repair. As a crease or gouge is worked out with



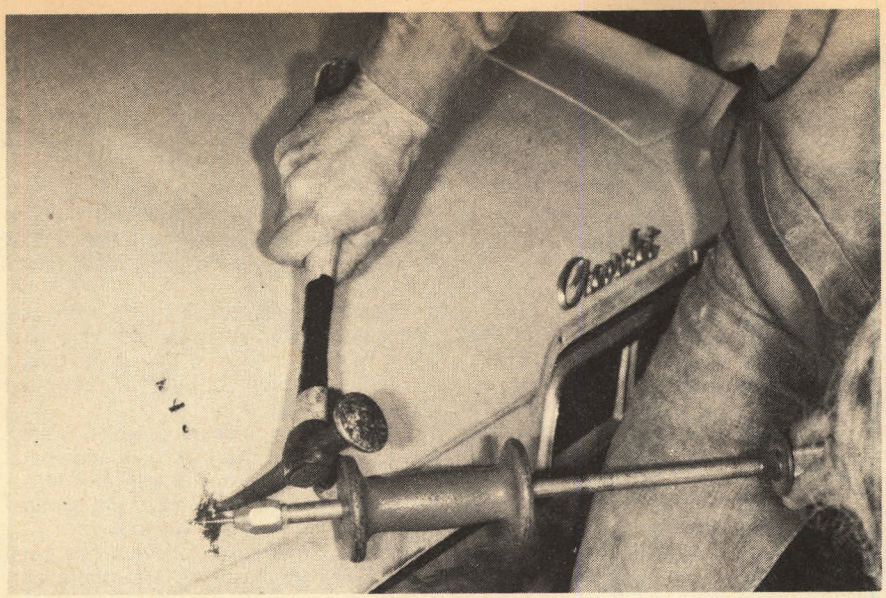
1. Body Files



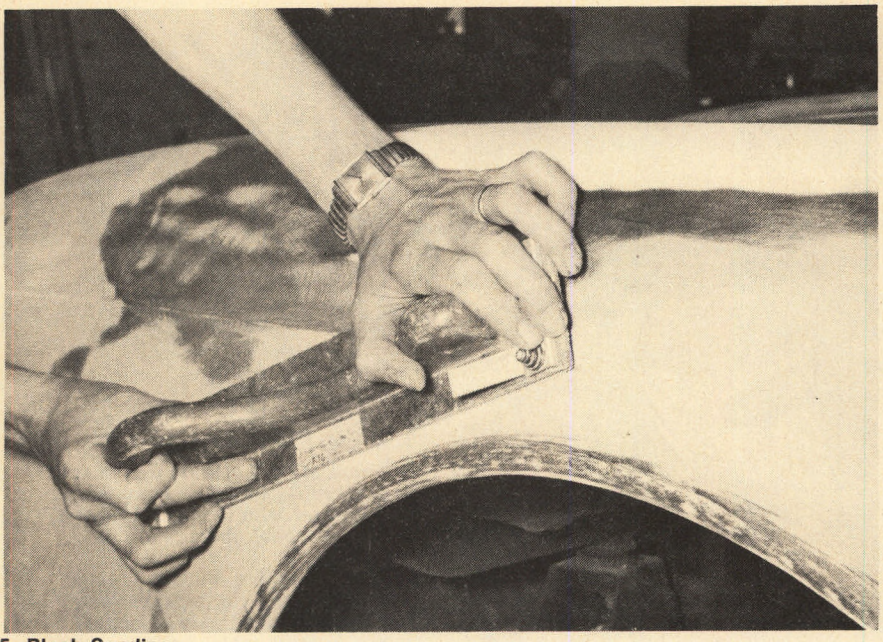
2. Using Hammer and Dolly



3. Welding a Patch Panel



4. Using Picking Hammer



5. Block Sanding

1. Files of various grits are used in shaping both metal and filler.

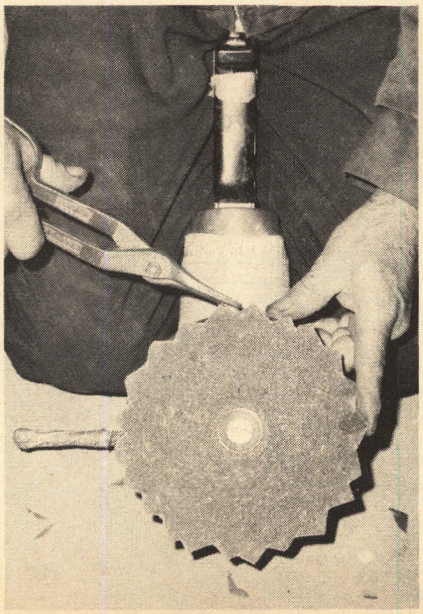
2. A hammer and dolly are the most basic tools in bodywork. You should never hammer on a panel without a dolly to back up the other side.

3. With basic welding knowledge and some sheetmetal, you can easily patch rusted out fenders and rocker panels. After this, the welds are ground down and smoothed into the main panel with filler. This often makes a better repair than just filling rust holes with "bondo."

4. The pointed end of this "picking" hammer is useful for tapping up the backside of small low spots.

5. Block sanding of large, flat areas is best done with shaper that uses replaceable sandpaper strips.

6. Here's the secret of using a disc sander on reverse-crown metal where disc edge would dig in. With disc edge cut this way, it's limber enough to flex with the contour.



6. Modifying a Sanding Disc

a hammer and dolly, the stretched metal involved will not want to flatten out properly, staying as either a slight crater or bump. It may be shrunk out.

Shrinking consists of heating a small spot in the middle of the stretched area where the metal has been made thinner. This will make the metal thicker, and it is easier than you might think. Put a small tip on the welding torch and heat a spot (about the size of a silver dollar directly in the center of the stretched area) to a strong cherry red. Be careful not to burn a hole. Immediately discard the torch and strike a hard blow with a body hammer directly on the heated spot. This will upset the metal and form a crater. Now, while the metal is still hot, hold a dolly against this crater from the back and tap the rim of the crater down with a hammer. Work around the rim in a decreasing diameter as the area cools. Quench about a 6-in. diameter with a water soaked rag to draw the heat expansion from the area, and you should be through. However, if the original stretched spot is large, it may require several shrinkings to straighten the panel. This is one procedure best observed before tried

LEADING

After welding, and sometimes because of excessive damage, a panel may need leading. This is a process of filling a sunken area to the surrounding metal height. The secret to leading is clean and properly tinned metal. The surface to be filled should be cleaned with a wire brush, extending at least 2 ins. beyond the rim of the indentation or welded area.

There are a number of leading fluxes, both liquid and powder, on the market, but as a general rule use whatever your local body man recommends. To apply the flux, warm the cleaned area and then spread the flux thoroughly. A ball of steel wool clamped in pliers can be used to scrub the surface and get a good tinning job. This is possible because the flux will dissolve the oxide present on any cleaned surface.

When the area has been cleaned and the flux applied, spread a small bit of lead solder to the surface, using a *soft* torch flame as with any kind of soldering. While the lead and metal surfaces are still warm, wipe the solder over the area with a clean rag. This will complete the tinning process, and any place that does not accept the tinning will certainly not accept lead.

Making lead stay on anything but a flat, horizontal panel can be a study in sheer frustration for the beginner. The only solution to this dilemma is practice and patience. Some lead is easier to apply than others, because of the metallic composition, so again let the local body man guide you.

In applying lead, use a soft flame and brush it across the tinned surface now and then to keep the metal warm (not hot!). Hold the lead stick near the tinned area and direct the flame over the stick end until the end begins to sag, much as a heated candle would. Quickly press the stick onto the surface. Keep this up

until enough lead is on the surface to fill the depression or welded area. As you are depositing the lead, occasionally brush the soft flame back across the deposited lead just to keep the area warm and pliable.

Shaping the lead is done with a wooden paddle frequently dipped in beeswax. The flame is passed across the lead deposit and as the lead becomes plastic (it loses the "sugared" look and gets shiny—be careful, because it is ready to run on the floor!), the paddle is used to push the lead across the surface. Paddle the lead over the entire tinned area and build it up slightly higher than the surrounding surface, scraping excess off onto the floor. Feather the edges smoothly with the paddle to reduce filing effort. While working the lead, if it keeps the sugared brittle look, you're probably working it too cold.

After the leaded area has cooled, it may be worked with the vixen body file. Care should be observed to keep the file flat, as the lead is softer than the surrounding metal and will gouge easily at this stage. The surrounding metal is the guide as to how low the lead should be filed, and if the area was tinned properly the lead will feather into the metal perfectly.

EPOXY FILLERS

More common with amateurs is the epoxy filler, normally called 'glass. There is nothing wrong with this type filler, although it is not as strong as lead and should not be used where a stress buildup is likely or at an edge where it can easily chip.

These plastic fillers, highly refined over the past 20 years, are popular because they are applied without heat and will not shrink or crack if properly mixed and applied. Always use the best epoxy fillers available as good insurance.

As with lead, the area to be treated with epoxy filler must be thoroughly cleaned. The filler is generally in a liquid form with a quick-setting hardener mixed just before application. Mixing must be thorough.

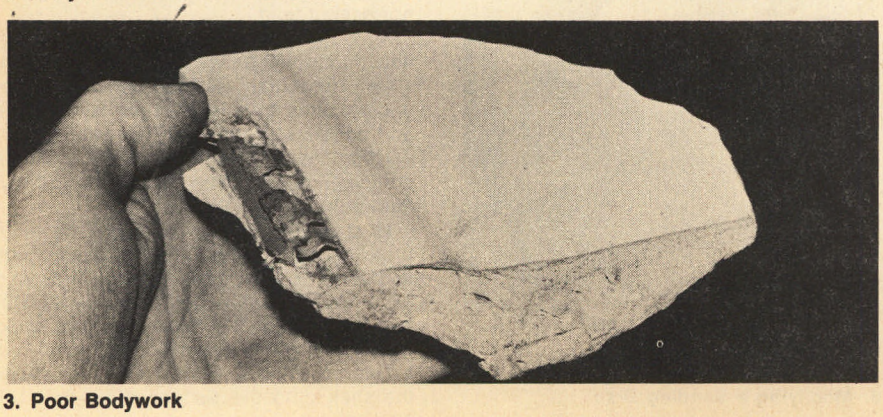
The mixture will set within 15-30 minutes, so work must go along quickly. Spread the mixture over the area with a wooden paddle or flexible rubber blade, as with putty.

The hardener added to the filler creates heat, and after an hour, the filler will be firm enough to be cheese-grated (roughly contoured with an open-cut plastic filler file).

After the rough shaping, which is easiest just before the filler gets superhard, the area is then sanded with a #80 paper, followed by 180 or 220 grit sandpaper, then cleaned and primed.

When either epoxy or lead has been used, always clean the area thoroughly with a cleaning compound such as

1. Bodywork Tools and Materials



3. Poor Bodywork

2. Mixing Fiberglass Filler

1. Some of the common tools used in body repairs include spray gun, hand riveter, and various fiberglass fillers and repair materials.

2. Body fillers are made by mixing fiberglass filler with a small "dab" of hardening agent, which should be mixed in thoroughly. By varying the amount of hardener used, you can mix the filler to harden slowly or in a hurry. Don't add too much though, or the filler will actually heat up and crack off the repaired surface.

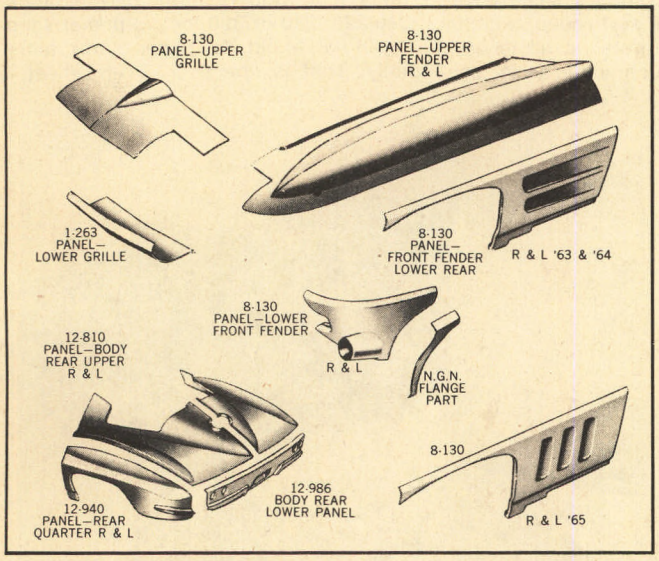
3. Never apply body fillers this thick! Road vibrations will cause it to crack and fall out. Instead, work the metal enough so little filler is required to make a smooth repair.

4. After sanding bare metal with a grinder or heavy sandpaper, deep scratches are sometimes left that cannot be concealed with primer. In this case, more sanding with a lighter paper is required.

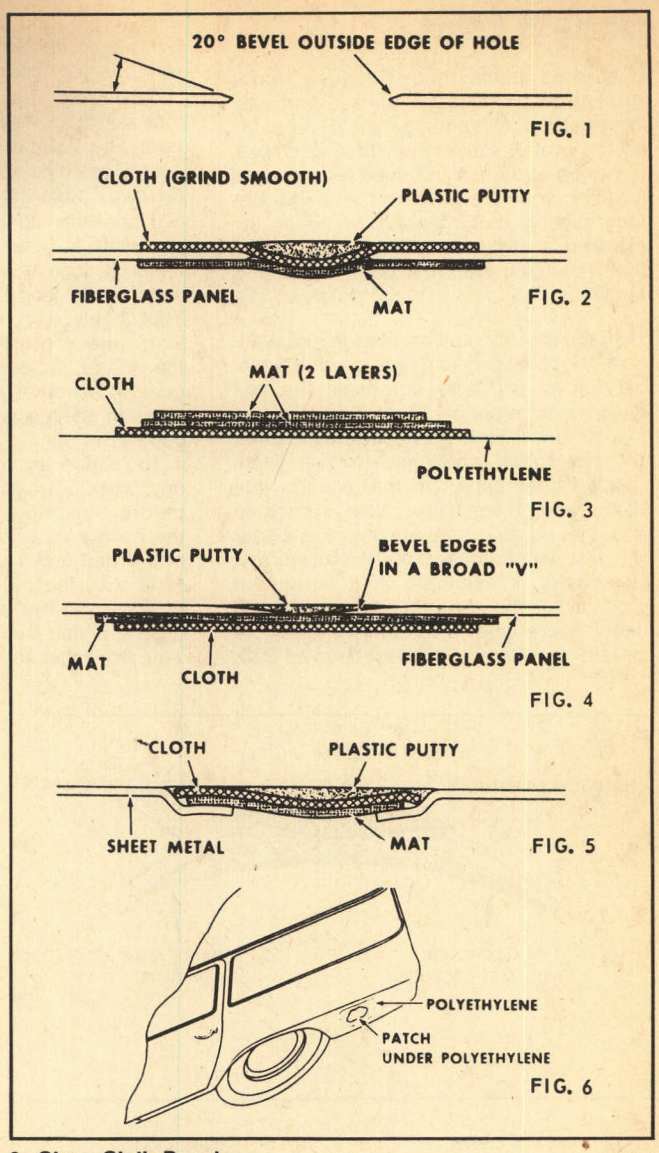
5. Corvette makes a number of replacement panels as well as molds. Local independent fiberglass companies offer panels also. Surprisingly, panel replacement of fiberglass is quite similar to sheetmetal repair.

6. Repair of fiberglass follows a set pattern as shown in Figs. 1–4. When metal is repaired (Figs. 5–6), edges must be flanged as indicated, fiberglass patch laminated to lips.

4. Grinding Marks



5. Fiberglass Replacement Panels



6. Glass Cloth Repairs

Met-L-Prep, then apply primer.

Body glaze or putty comes in a tube and is actually like thick paint. It is extremely useful for covering small scratches, pinholes in epoxy fillers, and for filling small valleys in feather-edged areas. It isn't designed to be used like regular body filler, though, and should never be applied very thick. For best adhesion the area should be primered *before* applying putty. The putty flows on easily with a squeegee and watersands supersmooth.

REPLACING PANELS

It is often more expedient to remove and replace a badly damaged panel rather than straighten it. Because replacement panels from a junkyard sell for about 30% of new cost, exploring such a source makes sense economically. However, there are certain things to watch for during an R&R (remove and replace) operation.

Make sure the mounting area has been straightened and aligned, or the replacement panel will not fit.

Take that fender again. If the damage was heavy enough, the mounting near the door may have been bent. Surely the inner splash panel has been bent, and the radiator-core support may also need straightening.

If the quarter panel must be replaced, then do a similar job to the crumpled panel. Often the replacement panel can be mated to the car beneath a beltline or fender molding.

If this is possible, overlap the top piece so water cannot slide down the joint and cause excessive rust, then braze each end of the mated joint. The overlap will be hidden by the chrome strip, so secure the joint with metal screws or (even better), use pop-rivets.

PAINTING

After all the bodywork has been completed, in preparation for a good paint job, every piece of chrome trim should be removed from the body. There are a few pieces that can't be taken off, for one reason or another, but the majority are removable. Reason for the extra work is to save extra work. That is, mask-taping the trim properly is a time-consuming project, and although it only takes about one-fourth the time of complete removal, there are other ramifications. In the first place, if you miscue with the tape, you can botch an otherwise good paint job. Secondly, if you take the trim off, the entire body gets painted, under trim and all. Thirdly, the area around trim is a perfect place for wax and other types of film buildup, and if you're not very thorough with your preparation, this kind of film will ruin the paint. And finally, it's just a devil of a lot easier to prepare, paint, and finish a car that's minus trim. Incidentally, if the trim is held in place by stationary clips (the clip bolts to the body panel and the trim piece snaps away), don't go to great effort removing the clips. Just paint them.

In addition to the trim, take out the grille (so the cavity can be painted); remove the bumpers; remove the rubber bumpers from the hood, deck lid, and doors; and lastly, peel the rubber wind lacing seal away from the doors and deck lid. Be careful, for you'll want to reuse this seal if it's still good. If not, you can put on new rubber, either standard or universal type. In case you really want to be meticulous, remove the door upholstery panels and kick panels. These are difficult to tape off, and the little extra effort is worth it.

SANDING

It isn't important whether you feather-edge the repaired areas or sand the un-

blemished paint first. Because water sanding is the fastest, cleanest, and easiest method of sanding, you'll probably do the overall sanding job first. This way, if the job stretches out over several days (nothing wrong with this), the slight surface rusting that's bound to cover the repaired areas will be taken off in the feather-edging step just before primer is applied.

Sandpaper for automotive use is available in both dry and wet-or-dry types, but for all practical purposes, the wet paper is far superior. The wet-or-dry type may be used either way, and costs about 10¢ per sheet, which means that you'll spend $1 for paper on the average job. Using water keeps the paper lubricated and the pores clean so that the paper will last much longer than if used dry. Wet-or-dry is available in a variety of grits, from 180 through 600, and you'll need several sheets of different rating. A couple of 180 grit, at least four of 220, four of 320, and later some 600. In addition, pick up two sheets of dry #80, which is very coarse.

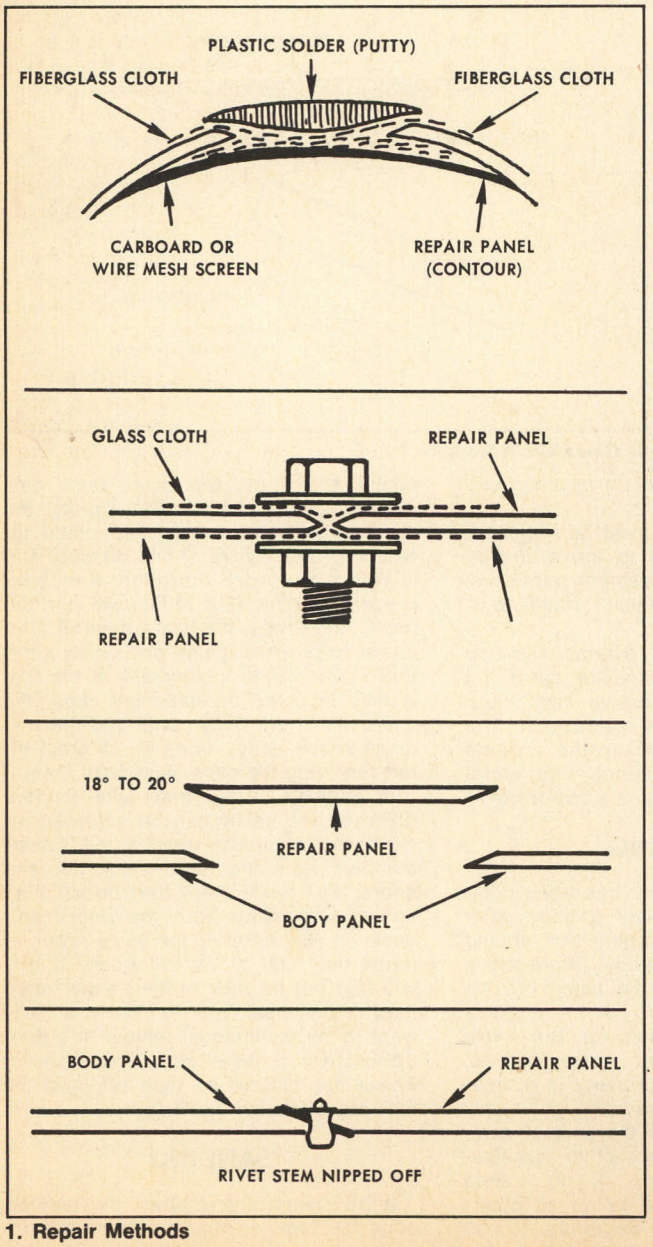
Obviously, it's wise to pick a place that will drain well for your sanding location. The residue from sanding actually acts like a mild stain, and it can discolor driveway concrete if left standing.

If possible, use a hose for water supply, with a bare trickle available at all times. If such is impractical, a bucket of water and good sponge will suffice. Thoroughly wet the surface before you start, and if possible, do the sanding in the shade, if for no other reason than comfort. Another hint, you might as well plan on getting wet, for you will before you're through.

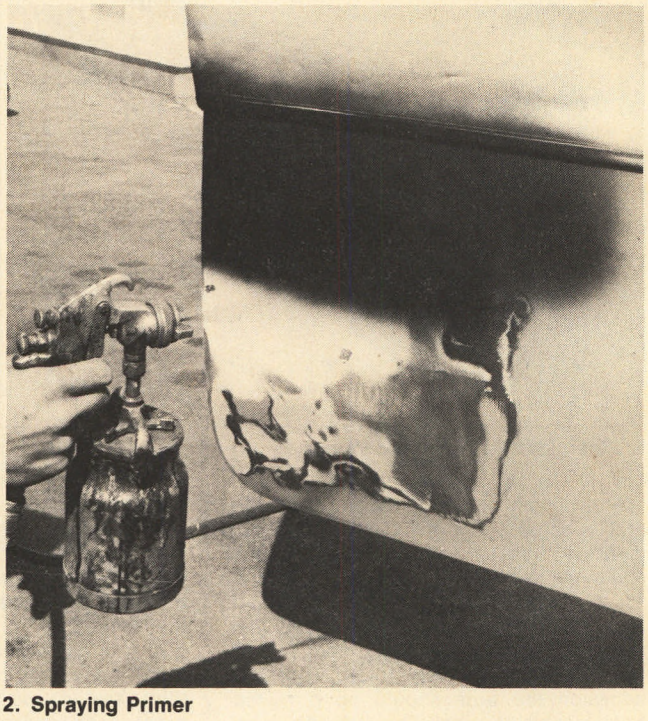
The top is as good a starting place as any; work down to the hood and deck lid before attacking the side panels. Hold the hose in one hand, keeping the metal end from making new scratches, and sand with the other. Direct a small flow of water on the work as needed, which means a fine film of water at all times. You won't get too much water as far as sanding is concerned, but too much will make it messier on you. When you're getting just enough water, the paper will glide without grabbing, but will have enough drag to tell you it's cutting.

The sanding pattern is extremely important and can have drastic effect upon the finished job. Work in one direction as much as possible, preferably lengthwise with the panel (much like the grain in wood), and never, never in circles. On many panels, such as the top rear windshield and rear windows, the lengthwise direction will not get around the windows well, so the direction must be changed to fit the circumstance, but the pattern here will be straight cross-grain effect.

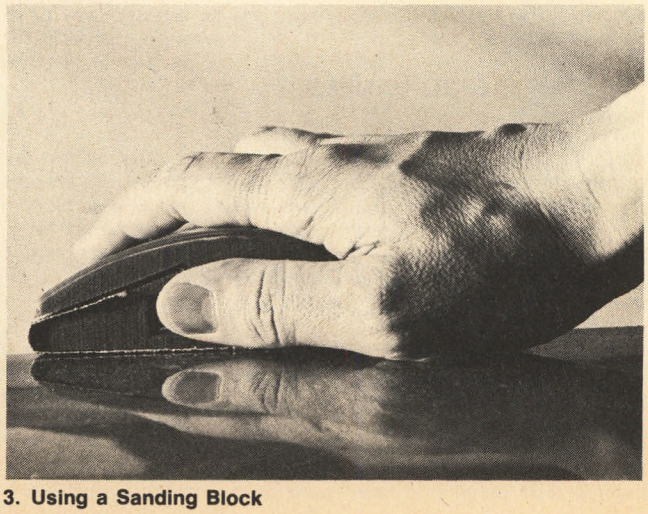
The paper may be held either by hand or with a semi-flexible sanding block. The block is very good for large panels, but the hand conforms better to curves. If a block is used, tear strips from the sheet just wide enough for the block. Use 220, 280 or 320 for pre-primer sanding. If hand-held, the paper is torn differently. That is, the 9 × 11-in. sheet is



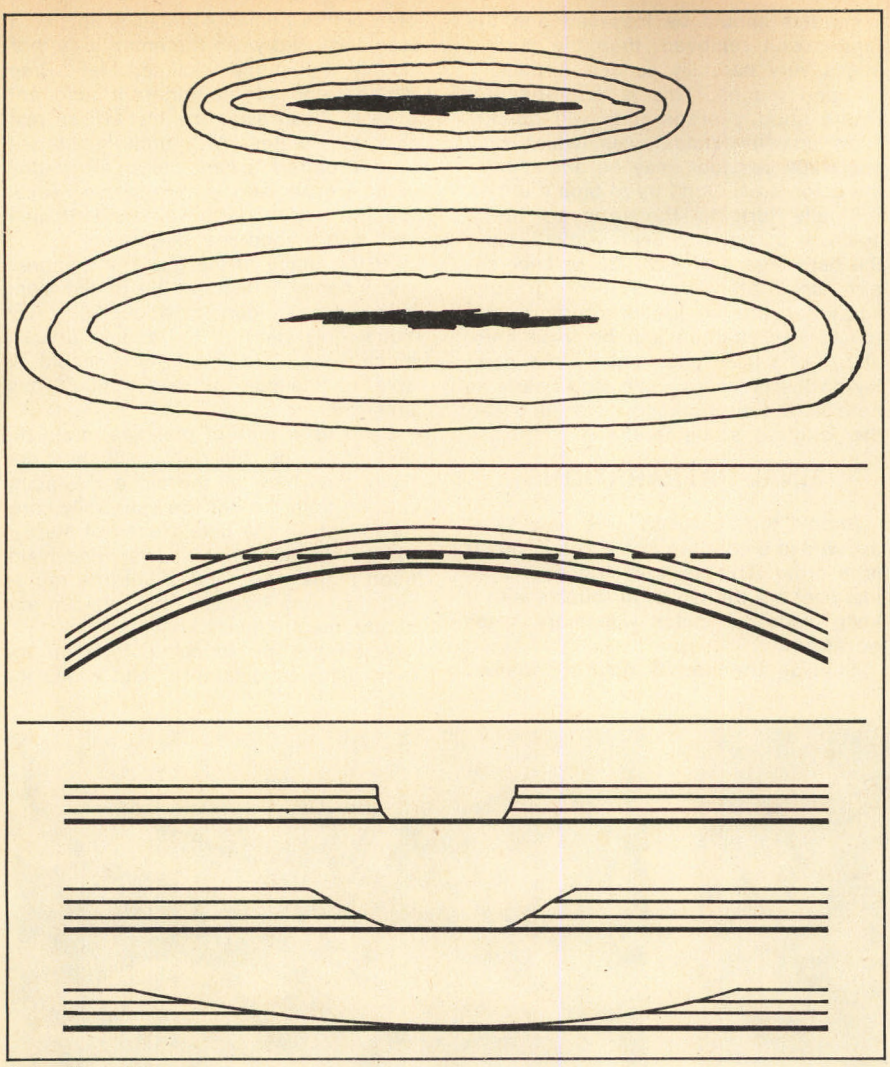
1. Repair Methods



2. Spraying Primer



3. Using a Sanding Block



4. Featheredging

1. High-crown area damaged in collision can be replaced by using a supporting mold from inside. It may be necessary to bolt or rivet panels together to get them flush during initial repair.

2. When you think you have a panel pretty smooth, lay a coat of primer on it. Sanding the primer lightly will reveal if there are any high spots still left in the panel.

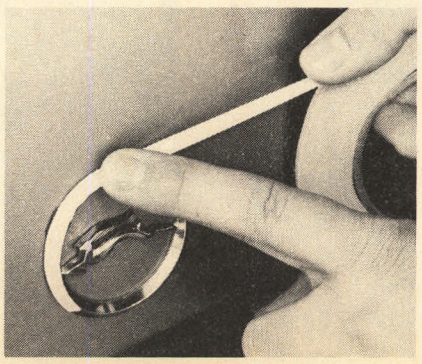
3. Sanding blocks like this made of hard rubber are inexpensive and do a much better job than using the flat of your hand.

4. These three drawings show how to featheredge sand a spot or chip. The larger the feathered circle. the better the result. Paint on a crowned surface will tend to sand flat, and must be radiused. Narrow scratches must be flared into area.

5. Thin putty or "glaze" spreads out almost like thick paint and is just the ticket for filling small sanding scratches or feathered-out nicks. The area must be primered before using putty, though.

6. Naturally, before any painting is done, the car must be masked off. This can be done for the most part with ¾-in. masking tape and sheets of newspaper. Narrow tape can be used on emblems like this, but the best results are obtained when all chrome is removed for preparation and paint.

5. Spreading "Glaze" Putty



6. Masking Off Trim

turned on its side, folded together, and torn down the center. Each piece is then folded triple, leaving one face toward the paint, one toward the hand, and one folded between the two exposed faces.

When sanding by hand, keep the entire hand in contact with the surface, not just the finger tips or side of the palm. However, for specific areas, these two pressure points may well be used to advantage.

After the entire area has been sanded, let it dry and check to make sure every inch has been covered. Any streaks or corners missed must be touched up.

With the biggest part of the surface sanded, attention can be directed toward the repaired areas, scratches, and chips. Getting these places feather-edged properly is vital to a good finished product! This cannot be over-stressed.

Feather-edging a large area, such as around a straightened place on a fender, is much simpler than small chipped spots. This is where those pieces of 80 grit dry sandpaper come in. To speed up the job, attach strips of the #80 to the sanding block (or to an electric or air-powered "jitterbug" sander) and do the rough-edging first. This paper cuts very fast, and leaves deep scratches, so use caution until you're familiar with it. With the rough production paper, it's best to sand with the edge, much like walking around the shore of a lake.

After this initial fast cut, switch to 220 and the block, plus water, and repeat. The idea is to feather the break between paint and metal over a wide area. There will be at least two paint layers showing, the color coat and the primer/surfacer, and on older cars the number can be as high as eight or nine layers. The wider the band of each paint layer showing, the better the feather-edging job! A 1-in. band means a much better job than a ¼-in. band. Finally, sand the feather-edged area in the direction of the overall panel sanding job.

The scratches are easy to remove if they're only one coat of paint thick. Just a little more localized pressure on the paper will do the job, but the "trough" should be feathered as much as possible. The little minute rock chips along the car front and around the wheel openings are harder to remove, and because of their sheer number, it's best to use a block or electric/air jitterbug. You can rent one of the handy gadgets, incidentally, for $3 a day. When the rock chips are really numerous and deep, resort to an initial attack with #100 paper, then follow up with the finer grits before priming. When this happens, the entire area of color coat is usually removed, but the effort is absolutely necessary.

Chips on the rest of the car, such as around exposed hinges or door openings, or what have you, are really the hardest of all to feather-edge. This is because their size means the feather-edging will leave a sort of smooth crater. Although the paint may be thin, the crater will really show up (even if properly feather-edged) in the finished job if you're not careful. The best route to follow when fixing up chipped places is to make the feather-edging area several times bigger than the chipped size. If

there were several coats of paint on the car, the crater might best be filled with a thin coat of putty after the primer is applied. The important point is, make a chip crater as smooth as possible, flowing gradually into the surrounding paint.

Be careful when sanding next to chrome, aluminum or glass, as the paper will cut these surfaces quickly. Next to chrome, slide the index finger (or little finger) off the paper and use as a guide. The same goes for the other materials, too. With a block, just be careful.

The edges of all opening panels, such as hood, doors, ect., should be sanded to bare metal with the block. This won't be hard; paint here is usually minimal.

The door jambs and door edges should be washed clean of all accumulated dirt and grease, then thoroughly sanded with both paper and #00 steel wool. The steel wool gets down into all the little irregularities the paper can't reach, otherwise the final paint might not bond securely.

Fenders should be loosened and the fender welt removed, then the mating edges very carefully sanded, especially chipped places. This is one location where shoddy preparation will quickly show up. New fender welt, which only costs 20¢ per foot, may be added after the color is on. Don't try to tape it off!

Finally turn to the repaired areas again. If a spot has been worked, sand the bare area well with 220 or finer paper, until all rough file or grinder scratches are no longer rough to the touch. The jitterbug can be used here, also. Don't use rough paper, and don't lay on the pressure. Lead isn't nearly as hard as the surrounding metal, and neither is 'glass, so be careful.

FINAL PREPARATIONS

Should the fiberglass area have what appears to be blisters, some further repair is in order. This sometimes happens, so just peel out the blister air bubble with a knife blade and patch with more 'glass or resin.

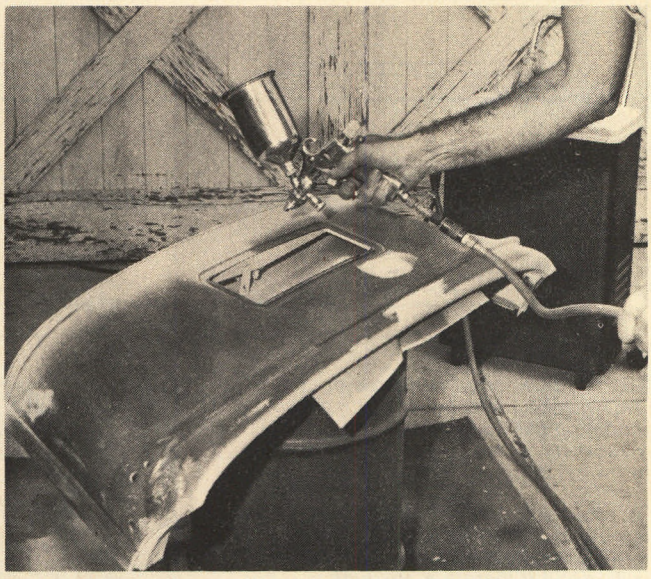
Special attention is paid a repaired area before primer/surfacer is applied. If lead was used wash the entire area thoroughly with properly diluted Met-L-Prep, which removes the inherent acid and grease. Wash away the Met-L-Prep residue with water. With both 'glass and lead repaired areas, clean thoroughly with grease and wax remover (even though they've been well sanded), then spot with a good coat of primer.

At this stage of the game, a compressor is handy, which can be rented along with the paint gun for about $8 a day. You'll only need it for a day (actually much less). The compressor should be able to maintain a steady 60-80 lbs. pressure.

Build up a tank of pressure, drain the tank of any oil (the renter will show you how), then blow all the dirt and sanding residue from the car. Be especially careful to get all the little pieces of stuff in the cracks around windows, windshield, hood hinges, etc. Use a lint-free rag as you go along to clean the surfaces and all chrome and glass areas.

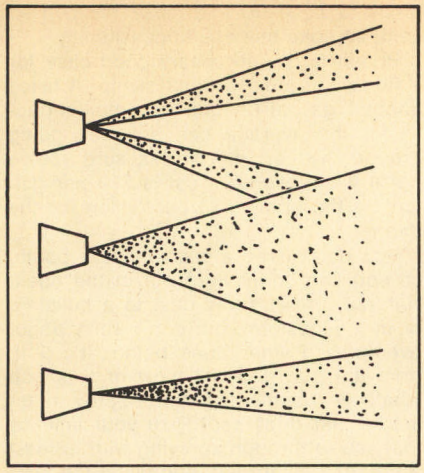
When the car is clean, tape off the trim, glass, and interior, and cover the

1. Paint Spray Booth

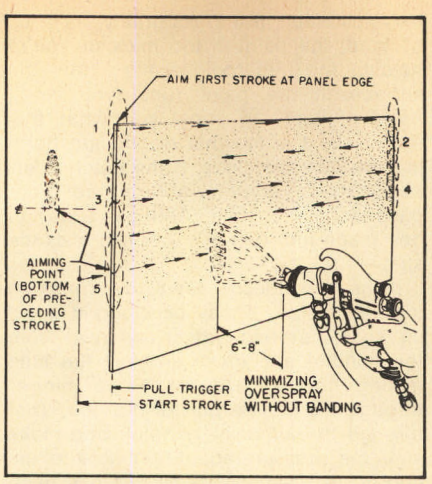


2. Gravity Feed Spray Gun

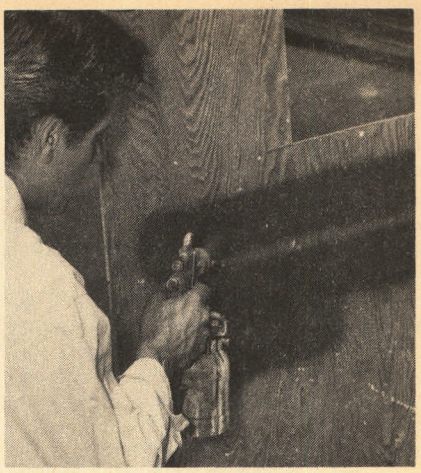
3. Marbles For Agitation



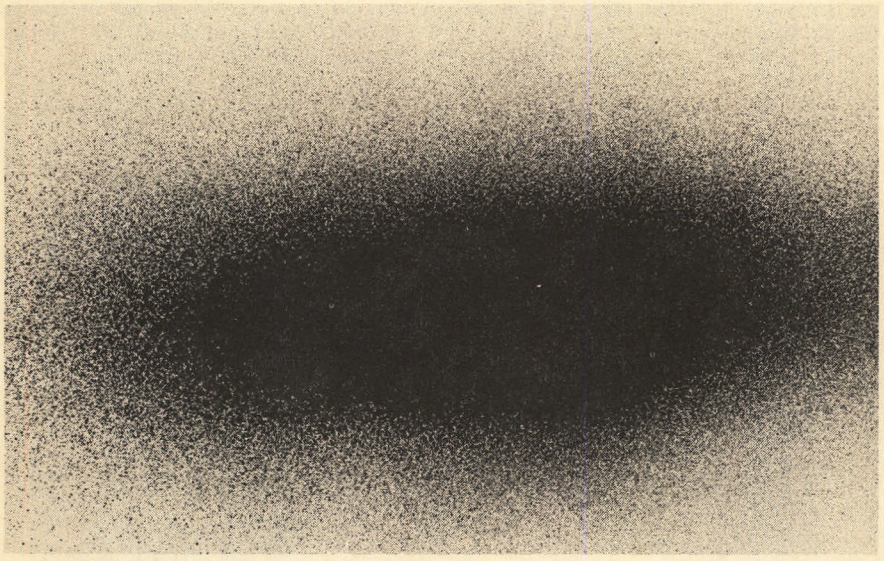
4. Proper Spray Pattern



5. Overlapping Each Pass



6. Testing Spray Pattern



7. Poor Pattern

1. You may not have a professional spray booth to paint in, but good jobs have been done by amateurs in a garage with floor wetted down, or outside on a calm day.

2. There are many kinds and brands of spray guns. Pressure, siphon and gravity feed (like this model) guns all have different capabilities.

3. When painting with metalflake or other metallic or iridescent paints, a few marbles or clean bolts in the paint gun will help to keep the metallic elements in suspension.

4. Spray gun pattern is critical in getting good results. Top pattern is too wide, gun needs adjusting. Middle pattern is just about right, at about 8 ins. from the gun. Bottom fan is much too narrow; this will load the paint on too heavily.

5. Practice making even strokes with paint gun, starting each pass "dry" and adding trigger at end of each stroke. Overlap must be just right or paint, especially any of the metallic types, will streak.

6. Before starting on the car, it's a good idea to test the spray pattern on something unimportant first.

7. This test spray pattern is too coarse or too wet, shows a need for an increase in air pressure of 5 lbs.

engine and the seats with an old piece of anything handy. Tape newspaper or wrapping paper around the engine compartment opening, and around entire door opening. Tape off the door upholstery panels and the glass molding if they haven't been removed. Keep all this paper as flat as possible, so debris can't fall into the folds and blow out later.

As you'll find, taping can be quite a maddening procedure. The best width to use on cars is ½ or ¾-in., which costs about 75¢ per roll. You'll need one or two rolls for the average car. When applying the tape, work over at least an arm-length stretch, rather than in short 3- and 4-in. distances. This makes following an edge infinitely easier, and the whole job much faster. For instance, to tape the long side molding, stick the tape end to one end of the molding, hold it there with the next finger, then unroll about 16 to 24 ins. of tape. Run the finger down this stretch, pushing the tape against the molding as you go. By sighting down the tape, you can get it exactly at the edge of the molding. If a little tape gets on the painted surface, run a razor blade parallel with the surface and cut away the offending tape. This tape must be removed, or an unpainted area, which shows up like a sore thumb, will be left!

When the entire car is taped, mix up the primer/surfacer. Always remember that neither lacquer nor acrylic will go over enamel in color coat form! The only time this can be done is over a factory-baked enamel job, where the paint is dry clear through. Even baked enamel from local shops is likely to blister when covered with the hotter paints. This applies only to the color coats, and not to the primer, which will cover with no adverse effects.

SPRAY GUN TECHNIQUE

No matter what kind of paint will be finally used—enamel, lacquer, or acrylic—use a multi-purpose primer with the appropriate thinner. Mix according to the can directions, which is about two parts thinner to one part primer, and stir thoroughly. For primer, a good all-around spray gun head will do, something like a #30 on the DeVilbiss and #362 on the Binks. Adjust the gun so that the spray fan is about 8 ins. wide at a point 12 ins. from the gun head. If the fan is too wide, there will be a thin spot in the middle; if it's too narrow the pattern will appear as a tight band. The fan adjustment is the top knob above the handle. The second knob is for material adjustment, and won't concern you too much at this time.

Make several practice passes on a piece of cardboard, with the compressor setting at 60 lbs. constant. With the DeVilbiss, keep the gun 8-12 ins. away from the surface; make it 10-12 ins. with the Binks. Notice that when the paint gun trigger is first depressed there is a moment when only air comes out. Following this, the paint comes. Practice making a smooth pass, keeping the gun a constant distance from the surface until the pass (which should average about 2 ft. per swing) is completed. Start the pass on one side, swing horizontally to the other limit, raise or lower the gun nearly a fan width and go back. Keep the gun parallel to the surface, so that one end of the fan isn't closer to the surface than the other.

As soon as you feel confident with the paint gun (don't worry too much, because primer dries relatively fast on the surface and it's easy to fix up a botched area), set it aside and get the car surface ready. Wash the entire car with a good wax/grease remover, then again blow away dirt, etc., from the cracks.

Start with the door, hood and deck lid openings. Spray the primer on evenly, in

smooth strokes. When these are done, allow them to dry for 10 or 15 mins., then close the openings and start on the big outside metal.

The previously primed spots where metalwork was done must be sanded with 220 or finer paper, then wiped clean. Any small spots of putty should be treated likewise.

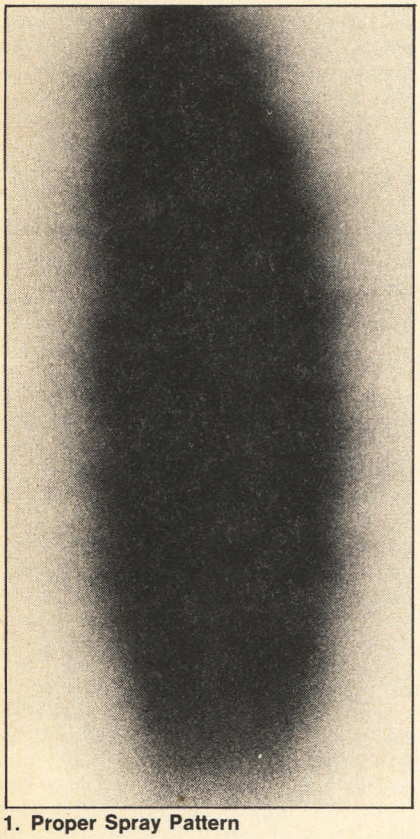
Start spraying on the top, which is the hardest to reach, and follow these handy hints. Throw the air hose over one shoulder and hold away from the car with your other hand; wrap a piece of rag around the gun/cap connection point to keep paint from dribbling out when painting with the gun in a horizontal position (such as for the top, hood, deck lid).

If the paint is going on right, it will appear smooth and wet for just a bit after application. If it looks grainy, as if full of sand, the paint is too thick or you're holding the gun too far away from the surface. If the paint runs (you won't need anybody to show you what this panic is!), it is too thin or you are holding the gun too close. If the patch alternates dry-wet-dry, or wet-runny-wet, your pass is not constant. And don't stay in one place too long. It's just like a dance step—1-2-3, 1-2-3, etc.

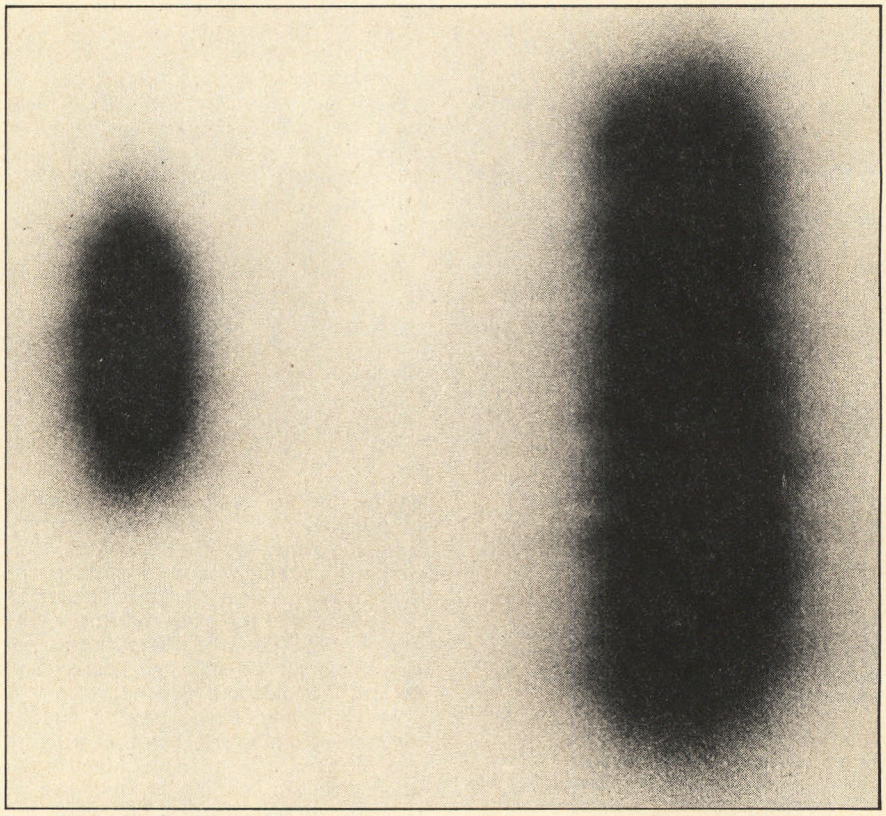
If the gun doesn't seem to be making a constant fan, it may be clogged up. If so, soak the head (which unscrews from the handle) and make sure all the little mixing holes are clear. Pour thinner through the handle part of the head (not through the air delivery hole), and make sure the pressure-equalizing hole in the cup lid is open. When all this has been done, spray a little clear thinner through the gun first to make sure it's really clean. As you use a primer gun, the primer—which is very thick anyway—tends to build up and close the cup lid vent, so poke this open occasionally.

Primer is the necessary good base for a fine paint job, so don't skimp. It takes about 1 gal. of unthinned primer/surfacer for the average car, so keep going around the car until you're sure you've got it well covered. Cost is $10 per gallon for the primer, $3 per gallon for the thinner.

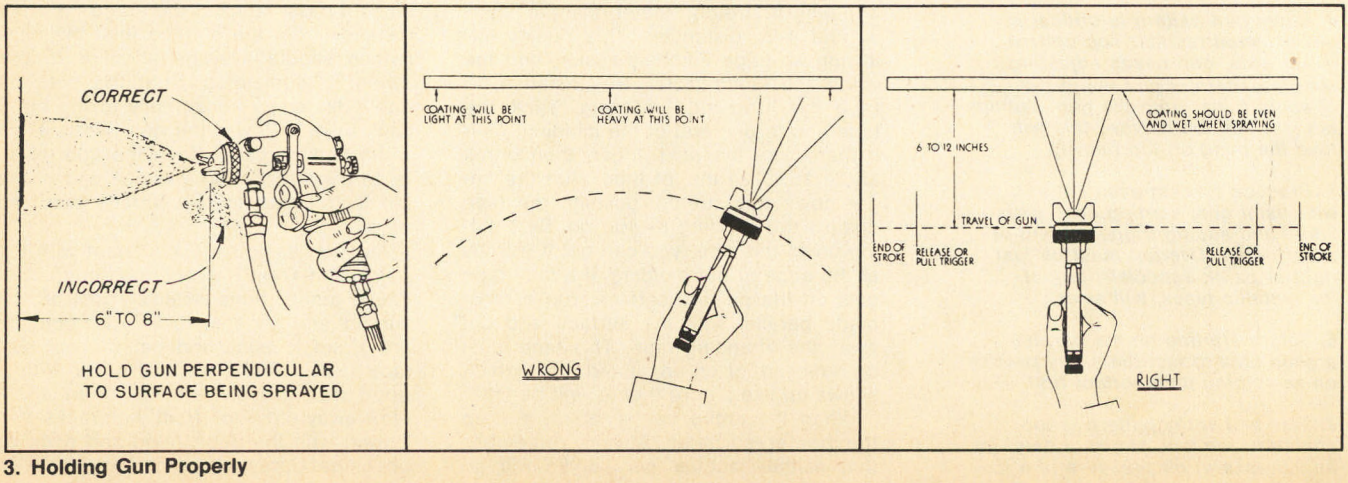
You don't need a special spray booth, so you can spray right out in the open. Naturally, don't spray next to a building, or in a windstorm, but don't worry about overspray. Primer dries before it's 5 ft. from the gun and will blow or wash off whatever it settles on. Don't spray under a tree that drips sap! Plan your time so that you're through spraying with at least 2 hrs. of sunlight left, and when the temperature is at least 40° or above. If spraying in the cold winter or inside when it's raining, use special thinner (the paint store will decide for you).



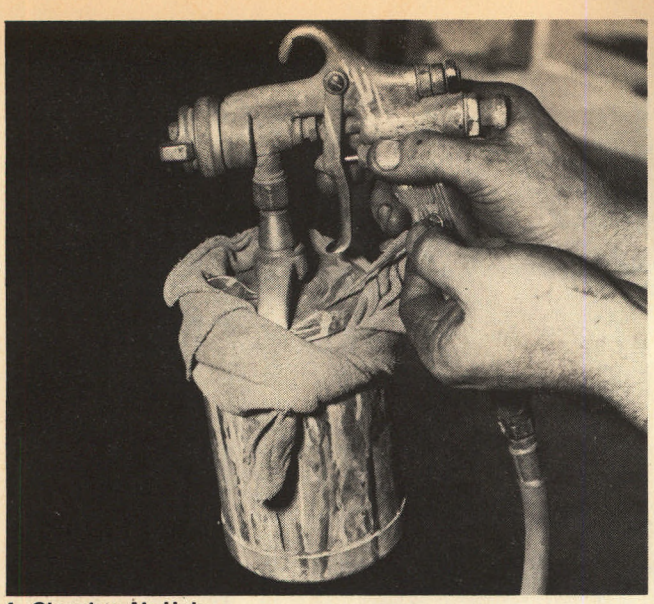
1. Proper Spray Pattern



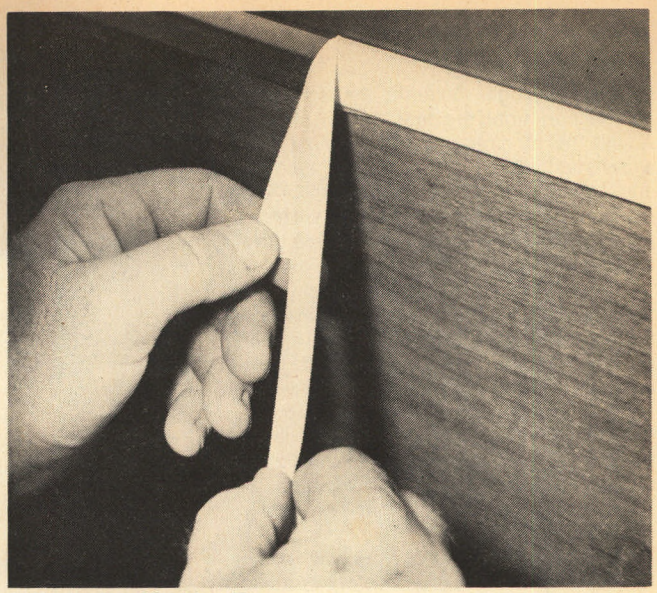
2. Patterns for Spots and Panels



3. Holding Gun Properly



4. Cleaning Air Hole



5. Removing Masking Tape

1. This is a normal spray pattern. Do not use excessive air pressure as it wastes material in the form of overspray, and ruins paint surface.

2. The small spray pattern here is used for spot repairs. The larger pattern is used for panel repair and complete refinishing jobs.

3. A spray gun is nothing more than an air brush and must be held same distance from panel throughout stroke. When adjustments and stroke pattern are learned, most of the painting battle is won.

4. With guns that have an air hole at the top, it's important to keep the air hole free by poking a wire through it occasionally. The rag is tied around to catch any paint drips.

5. When removing masking tape from any surface, it's best to pull it back over itself like this, and always pull down away from newly painted panel or paint may chip.

Finally, if the car has slight waves in the panels that might be taken out by block sanding, a good trick is to spray a final coat of different colored primer. For instance, if the major primer color was light gray, finish with dark gray, or vice versa. Then, later on when you block sand, the thin top coat will come off but the other color will still show in low spots.

After the primer has dried for 20 to 30 mins., the tape can be removed. If you are painting over bleeders like maroon or red, the primer must be sprayed with a bleeder sealer to insure an even tone. Although it is possible to go right ahead and sand the car (dry) and follow with the color coats of paint, it is best to allow the primer to cure for several days, even weeks. The primer will dry and shrink, so allow about four weeks' time for a good quality job. You can drive the car meantime.

Scratches don't come in the paint can or from the gun. So, take it easy during the surfacer sanding operation. The surfacer will sand very easily, either dry or wet, and it's advisable to use 320 or 400 grit paper on surfacer. Remember this is the base for the color, and use of a coarser paper will leave scratches too deep for the color paint to cover.

Next, use the wax and grease remover solution, completely washing the car, even the smallest cracks. This is vital, for any foreign substance will invariably ruin an otherwise perfect job. For instance, just the marks left by your fingers will leave dark splotches under the final color. When washing the car with the cleaning solution, always use clean, lint-free rags (don't use shop towels, as they often are cleaned with low-grade solvents that contain contaminants bad for good paint adhesion). It's wise to use the special cleanser always, but in a pinch you can use lacquer thinner, applied with a very wet rag and immediately wiped off with a dry rag. Don't wait even a minute if you use thinner, as it is "hot" and will quickly soften the surfacer and may cause other damage to the paint below.

FINAL PAINT COAT

The car is now ready for the final color, and this is the precise moment most amateur painters get the jitters. It's also the time when one step must follow the other in rapid succession, so having the procedures well established in your mind will ensure best results.

What you do from now on depends a lot upon the paint you're using—the type, not the brand. Lacquer is the easiest to spray for the novice, followed by acrylic, then enamel. This is simply because the lacquer and acrylic dry much faster, compensating for many application errors—or at least, for a few.

Enamel paint, although hardest to actually apply, requires the least amount of overall effort, and is an excellent choice where maximum toughness is required. It gets its glossiness (shine) from a varnish used by the manufacturer. This varnish is made of a solution of resins with alcohol, turpentine, or amyl acetate. You must use enamel thinner with enamel paint. Although acrylic has received a big boost in use as standard finishes by several auto makers, at least one major company still uses baked enamel. A baked enamel job is superior to an air-dry job and is very durable, but unless you have a bake oven available, you're stuck with air-dry. For years now auto enthusiasts have considered lacquer the only way to get a superb paint job, but such is not always the case. It depends generally upon the painter. For the average person unable to afford a good lacquer expert, and not wanting to take the extra preparation pains necessary for lacquer, enamel is an obvious answer. It will cover scratches well, and can be used almost anywhere you desire.

Acrylic is like lacquer, in that it dries right away, but it is plastic-based (lacquer is cotton-based) and undergoes a chemical change as the paint dries and unites with oxygen. Acrylic must be sprayed differently and will not dry to maximum gloss if put on in one heavy coat.

Before starting the color spraying, it's wise to completely clean the spraying equipment, especially if it has come from the local rental emporium. You can rent perfectly good equipment, but make sure the compressor is in good shape (not pumping oil). Paint guns will differ, but all you're interested in is a good all-around nozzle (head).

Clean the paint gun thoroughly before any use, either with acetone or lacquer thinner. Acetone works faster. Remove the pot and nozzle, then soak everything for 20 mins. or so. Follow by brushing the pot inside, the top sealing lip, the sealing area on the pot cap (the sealing gasket must be good), the nozzle, and the gun head. Make sure all mixing holes in the nozzle are clean.

If enamel is to be used, thin it with two parts thinner to one part paint, pouring the paint into the cup through a strainer which will trap bits of foreign matter. Tighten the pot until secure, as paint might otherwise drip from the connection (the shop rag tied around this connection point will prevent drips).

Before blowing color on the waiting car, test the gun pattern. Start by opening the gun up by turning the spreader adjustment (top thumb screw above handle) all the way out, and backing off the

fluid screw (right beneath the spreader adjustment) until the first thread shows. Adjust the air pressure regulator to give a constant 40 lbs. pressure for lacquer and acrylics, or 60 lbs. for enamel. Hold the gun 6 to 8 ins. from the test surface, parallel to such surface, and give the trigger one full pull, then release.

The color coat is sprayed exactly like the primer/surfacer. However, some extra preparation might be needed if lacquer or acrylic is being applied over enamel. Just as a precaution, if the old paint is enamel, spray on a coat of DuPont #22 sealer, which will help keep the enamel from raising due to the hotter lacquer thinner. If you're not sure, always spray a test patch first. The sealer is always a good idea.

All the previous hard work will come to nothing if the final color coat is sprayed haphazardly. Before actually spraying any paint, practice the proper spraying swing. At all times, the nozzle should be from 8 to 12 ins. from the surface (individuals vary in technique, thus the difference in distances). Picture yourself facing the door of a car. You want to paint each individual panel, or panel group, with a full stroke, thereby reducing the number of overlaps to a minimum on each surface.

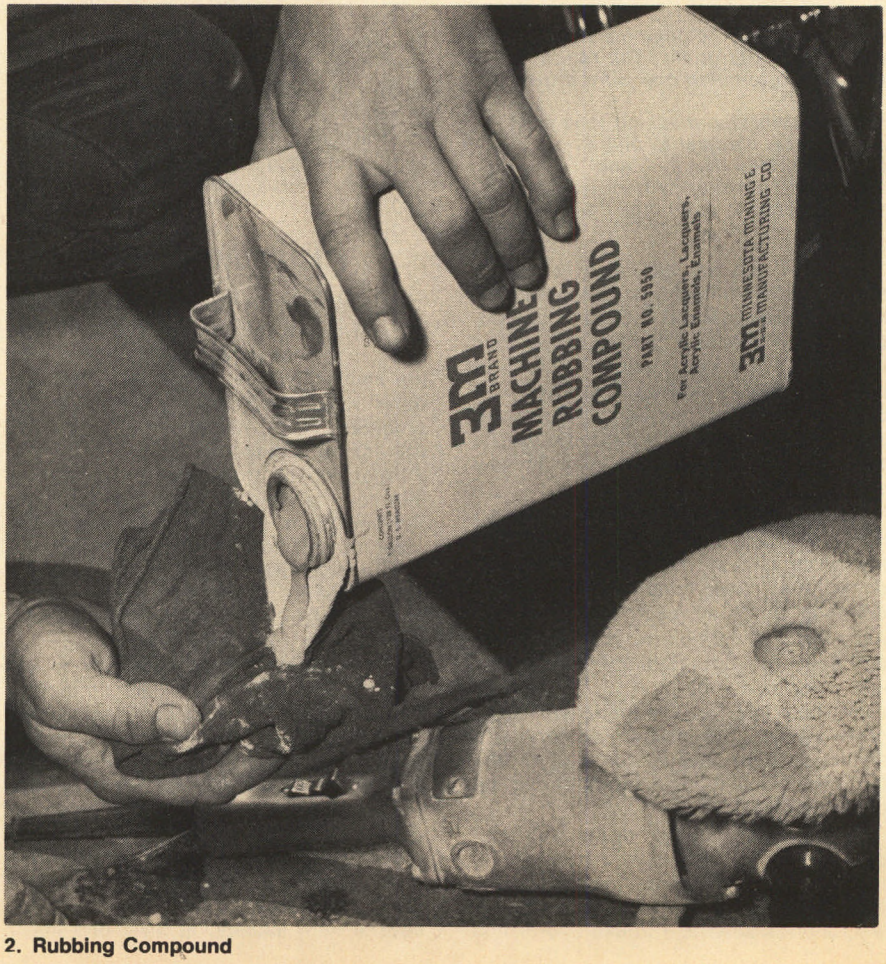
With the gun held at the left edge of the door, and the nozzle distance correct, twist the wrist so the gun is actually pointed lengthwise to the car. As the trigger is pulled, twist the wrist back toward the door. This makes the initial application of each stroke blend together at the overlap. As the gun comes to point directly at the surface, begin the smooth stroke across the panel. Not too fast, and not too slow. If you go too fast, the stroke will look misty; if too slow, the paint will pile up too heavy and try to run. Remember that it is easier to do a job with several thin coats than with one heavy coat. At the end of each stroke, twist the wrist away from the car in the opposite direction (or direction of the stroke).

Although the technique differs, most painters spray the door jambs, hood edge, trunk jambs, etc., before starting on the rest of the car. If you're careful during this phase, only a small amount of overspray will carry around the edge and onto the outside metal. If too much overspray gets around the opening, it may make the overall blending job too difficult. For lacquer or acrylic the area may be lightly sanded, for enamel the best procedure is a wash job with thinner before the paint hardens.

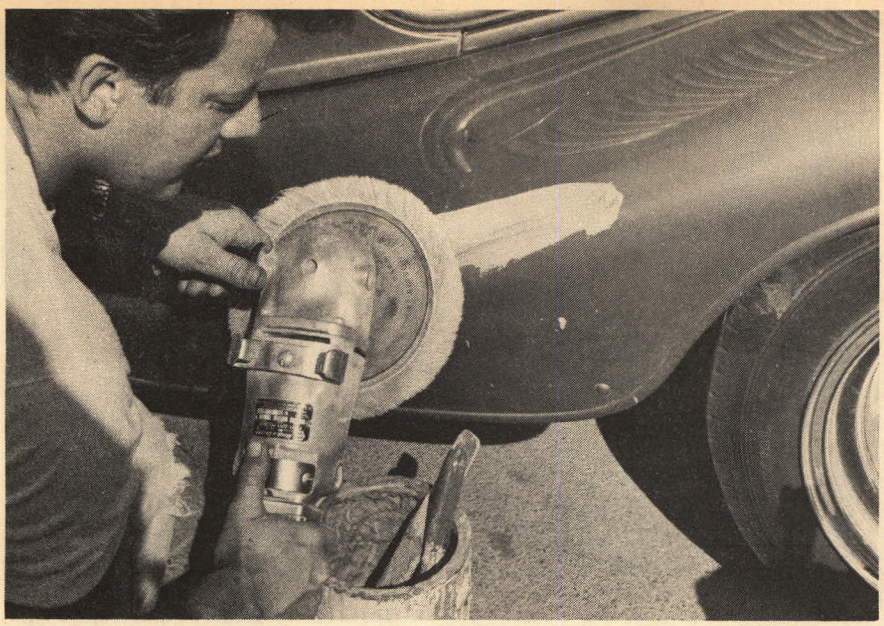
Because panels are sprayed one at a time, get into the habit of spraying consistently. Don't spray heavily in one place and lightly in another. As a panel is started, try starting the stroke slightly inboard from the panel edge and ending slightly short. As the next panel is started, the resulting overlap will keep the depth of paint constant.

The biggest single problem the amateur painter experiences is stroke inconsistency. The paint must overlap everywhere, otherwise it will appear streaked when it dries. It sometimes helps to

1. Taping for Pinstripes



2. Rubbing Compound



3. Buffing With Rubbing Compound

4. Cleaning Clogged Buffer

1. Pin striping is an art in itself, but if you lack a steady hand, you can make straight stripes with this special tape which is scored so strips can be pulled out to paint through.

2. After a new lacquer or acrylic paint job has cured (usually a week or two), the paint must be rubbed out to achieve its final high gloss. Be sure you are using the right rub compound for the type of paint used.

3. Paint can be rubbed out by hand or with a buffer. Go cautiously if you use a buffing machine or you may buff right down to the metal!

4. When compounding with a buffer, the fluffy sheepskin becomes matted with hardened compound and should be cleaned with a "ticking wheel."

5. Touch-up paints in all stock colors are available in most auto parts stores. For small nicks and scratches, tubes of touch-up paint with applicators can be bought at your dealer's parts counter.

5. Ford Touch-Up Kit

make horizontal strokes first, then vertical strokes, etc. The idea is to apply the same amount of paint everywhere on the surface.

If lacquer is being used, the drying time is such that it may be applied at random. However, acrylic must be allowed to "flash" before the next coat is applied (surface harden). Enamel is a slow drier, therefore it should not be applied all at once. The first time around, a very light tack coat is applied. This will become sticky in a few minutes and helps make subsequent spraying easier by increasing adhesion. The second coat of enamel is sprayed normally, but the amateur should never try to get all the paint on the car in one pass (2 gals. required for the average sedan).

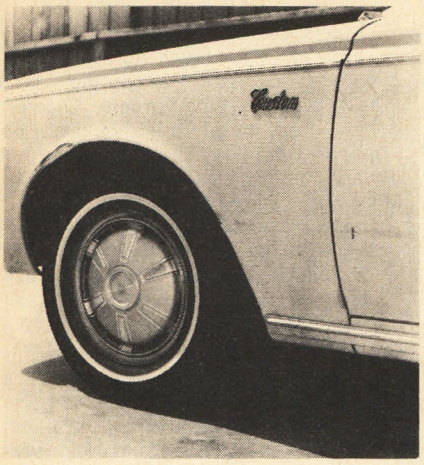
Starting with the top, spray each stroke evenly. If you load up a particular area, which is easy to do, the paint may sag or run. Don't panic, just continue with the spraying but stay away from that place. It is sometimes possible to stop a run in the early stages by simply backing away from the panel slightly and spraying nothing but air across the run. This will often give enough surface drying to hold the sag from advancing. When the first coat is dry, dip a tiny brush in enamel thinner and remove as much of the sag excess as possible. The idea is to soak up the excess rather than spread it around. After the sag has been carefully removed, fog a little paint over the area. If you do the job well, the little boo-boo won't be too apparent. On the next coat, go easy in the area of a run, again just spraying on a light fog coat.

An enamel job usually requires three coats—the tack coat, the first heavy color and the final color. After the last coat, wait a couple of minutes, check for sags and repair any if necessary, then leave the car to dry overnight. In fact, since enamel should be painted in a spray booth if possible, leave the car for a couple of hours before detailing.

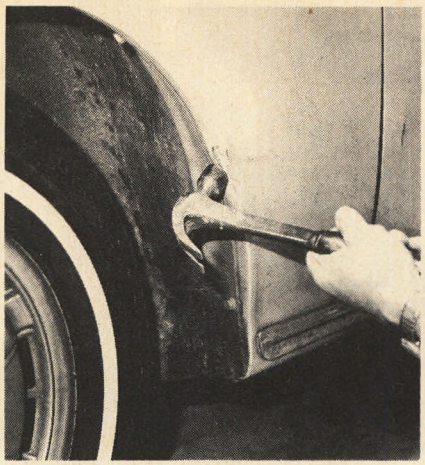
A note about enamel and moisture. They just don't mix, so if the floor is washed down before painting to settle the dust, let it dry before spraying. Temperatures shouldn't be under 60° or over 100° F. when the car is being sprayed, otherwise special steps are required. Special additives are available to control the drying time, such as DuPont #3656 (rather than normal 366/g) for acrylic, which will slow drying if the temperature is too hot. If painting is done when the weather is wet or cold, the color can "blush." That is, moisture is trapped in the paint, so a slower thinner or special retarder may be needed. The paint store will guide you here. At all times, follow the mixing direction of the manufacturer explicitly!

Although the enamel job can be done at one spraying, lacquer and acrylic require more elapsed time for the best job. If you have the time, spray the latter in several good coats, then allow to dry for a couple of days. Water-sand with 600 sandpaper, then spray several more coats. Whereas enamel doesn't require any after-spray special attention, lacquer and acrylic must be color-sanded with 600 sandpaper before the final rubbing out process (buffing).

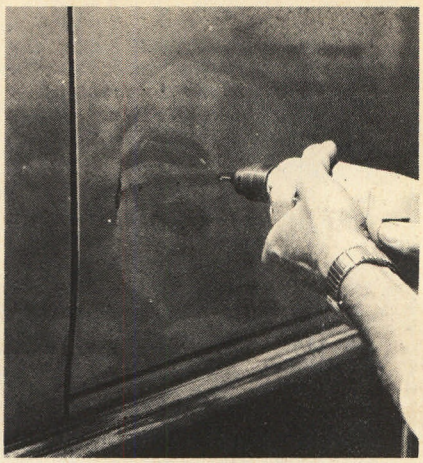
HOW-TO: Body & Paint



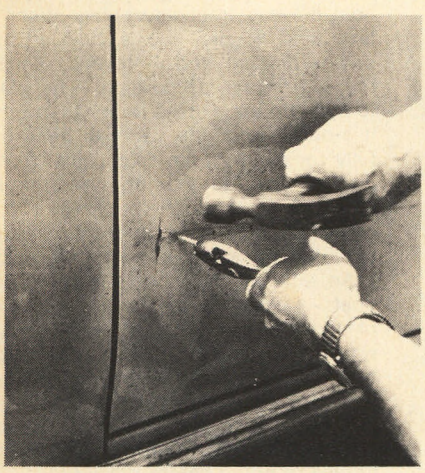
1. A scrape along the door sure doesn't look like much damage, but body shop estimates for repair (minus painting) could range from $88.50 to $99.25—something worth saving.



2. Without an awful lot of trouble, you can very easily restore partial shape and form to wheelwell dents by making a few well placed blows with an ordinary claw hammer.

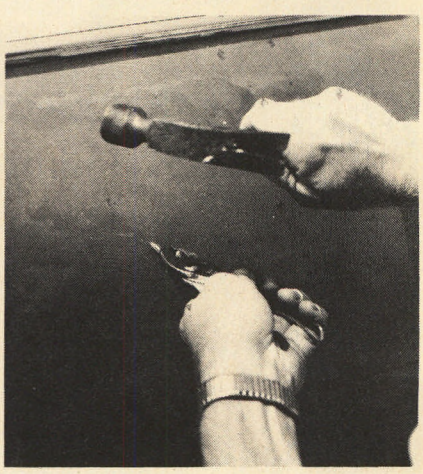


3. The next step in this process of pulling out creases is to carefully drill ⅛-in. holes along the center of the panel crease. The holes should be spaced about 3-ins. apart.



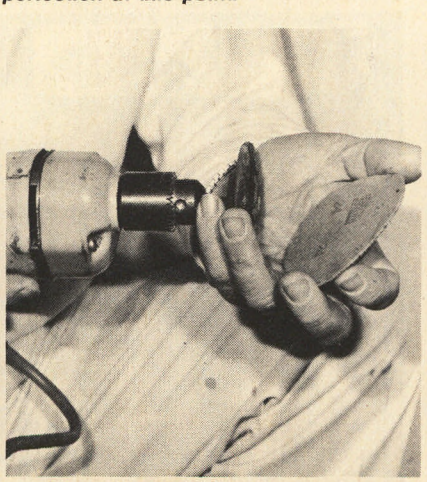
4. Thread a sheetmetal screw into first hole and pull it toward you. Use a pair of pliers and tug sharply. Then hammer above and below crease, while continuing to exert pull.

5. Continue pulling procedure along crease. By the time you're finished, it should be pulled back nearly to the original panel shape. Don't try for perfection at this point.

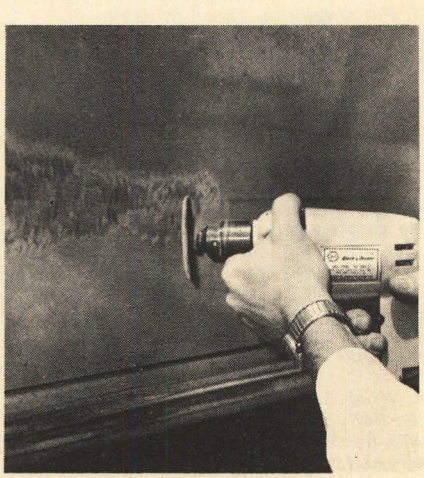


6. Check the panel carefully for any secondary damage. Here, there is a slight depression in the panel half-way between the major damage and the top of the panel on this car.

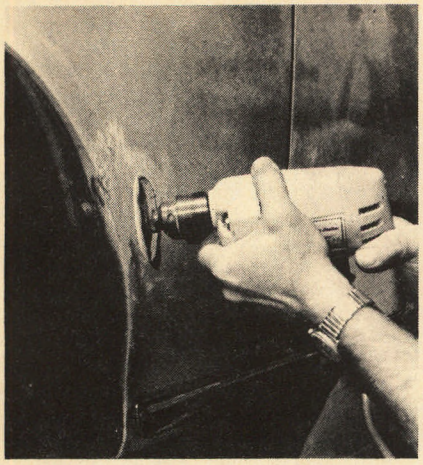
7. Once damaged areas appear near normal, run your hand over them. Don't worry about slight depressions. But raised surfaces should be detected and lowered to panel's shape.



8. Replace drill bit with a rubber pad sanding adapter. A #24 grit disc fits on the pad for grinding. Then apply firm hand pressure to the disc to make sure adhesive sticks.

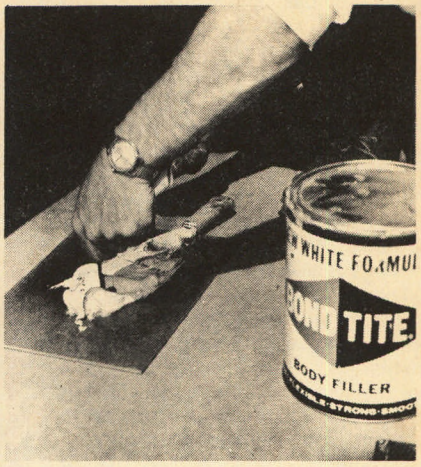


9. Grind along the creased area to the bare metal. This helps to restore the panel contour by cutting off the high spots, and it prepares the surface for a body filler application.

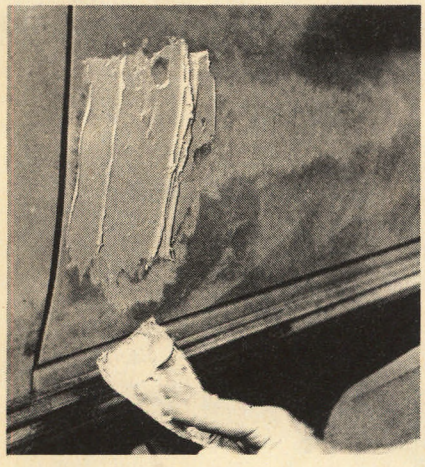


10. Now, the next step is to go to work on the fender and the wheelwell damage. But be especially careful when you do the grinding so that you avoid cutting through the metal.

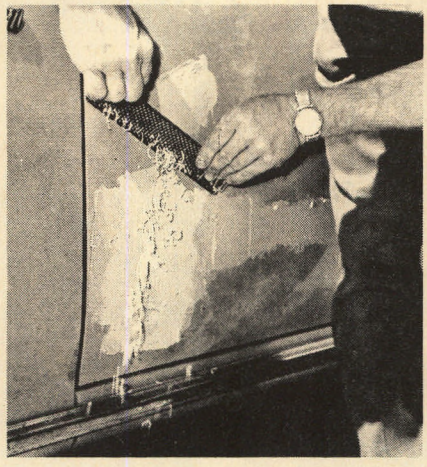
11. This particular dent was the most difficult. Hammering only restored contour about 50%; considerable cutting was needed to prepare it for the application of body filler.



12. Mix body filler and catalyst on fiber board or heavy cardstock. Follow directions on the can of filler. Work quickly because filler sets rapidly once catalyst is added.



13. Apply filler generously over the damaged area with a wide-blade putty knife. This is a rough application; its purpose is to fill low spots and to provide a base for shaping.



14. Fill all the other damage spots while you are waiting for the filler to flash off. When the filler is ready, use a "cheese grater" file to shape the contour to the original.

15. If you can't get the contour the first time around, apply more filler and refile. Once you do have it, a final application with a squeegee will fill any little pin holes or imperfections.

16. Hand sand with a folded sheet of fine grit paper. Be sure to feather the edges of the filler so that it blends smoothly into the undamaged area surrounding it in all directions.

17. Filing and shaping an area of heavy contour requires patience, but remember that the filler sets fast, and if you don't keep up with it, it may harden so much it can't be filed.

18. A coat of primer applied with a brush finishes the job. Total cost of the afternoon's work: $13.50. Before you spray a color coat, sand the primer lightly, and it's ready.

Body & Paint

Vinyl Body Parts

Over the past few years, the auto industry has turned increasingly to the use of polyvinyl and other plastics, both as a replacement for costly metal and as a means of offsetting the added weight mandated by the various requirements imposed by the Federal Motor Vehicle Safety Standards. For the most part, use of these materials has been restricted to the interior and engine compartment, but Pontiac's recent success with its resilient urethane nose section pointed the way for greater exterior use of the metal substitutes, and current models feature plastics to a greater-than-ever extent.

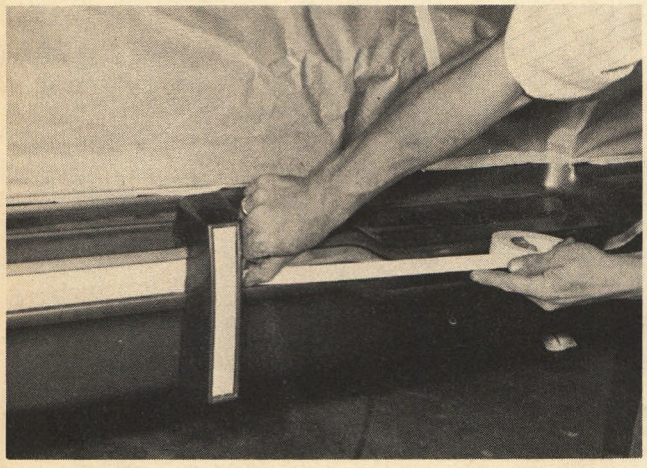
From the panels covering the gap between bumper and most car bodies to the Corvette nose/tail sections and Mustang II bumpers, the increased use of rigid vinyls, polyurethane, polypropylene and other exotically named plastics looks like a sure bet. Painted the same color as the body, many motorists are unaware of just how much vinyl graces the exterior of their new car until that inevitable fender-bender comes along.

If do-it-yourself body and paint work is your thing, you'll find that the painted vinyls offer some real challenges to the refinisher. Replacing the entire vinyl section—panel, bumper cover, etc.—poses no problem, as replacement units come factory-primed and ready to paint. But if you've got scrapes, scratches or surface gouges to contend with, you can't just whip out the trusty spray gun and go to it—unless you enjoy peeling paint off in long strips a week or two later.

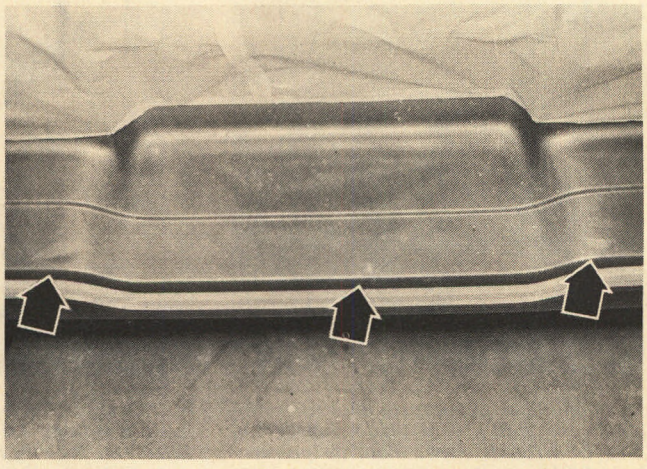
The type of vinyl involved doesn't really affect your repainting procedure—it's the type of paint used that makes the difference, as acrylic enamels and acrylic lacquers require quite different techniques and materials. Professional painters to whom we've posed the problems seem in agreement—you'll get better and longer-lasting results when working with acrylic enamels. In this case, the agents that bond the paint to the vinyl are added when you mix the color and the two are sprayed in a single coat. Acrylic lacquers require that you spray a special bonding coat first and then apply the color coat after flash-off. The trick seems to be proper measuring and mixing in one case, and following spraying directions to the letter in the other.

To give you a better-than-even chance to do the job right the first time, we've detailed both repair procedures for you in the following photo sequence, beginning with acrylic enamel applied to the rear bumper of a 1974 Mustang II. Follow these steps and tips faithfully and you should be able to do the job just as well as the professionals.

HOW-TO: Repainting Plastic Body Parts



1. Proper masking to protect against overspray is just as important in refinishing vinyl as with metal panels. Chrome-colored plastic inserts are taped for a neat job.



2. The problem areas shown are scuffs, scratches, and a slight gouge caused by a higher bumper on another car slightly overriding our Mustang II in a parking lot.

3. A thorough cleaning with a wax and grease remover such as R-M Pre-Kleano 900 is an absolute must. Apply and remove it before the solvent has a chance to dry.

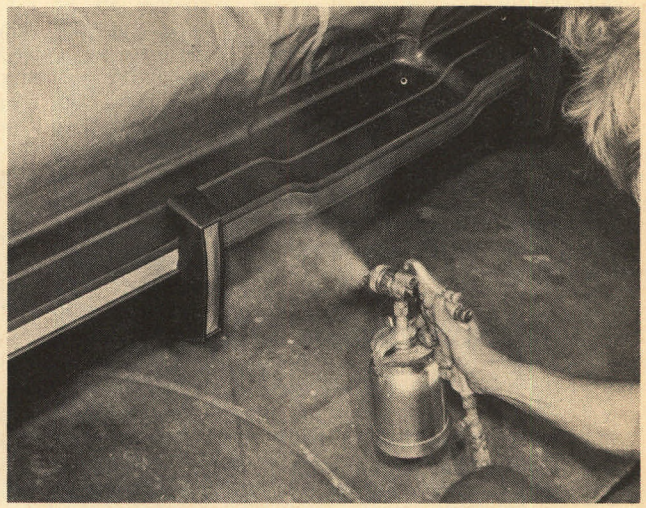
4. A 7447 Scotchbrite pad or #320 grit sandpaper is used to rough up the surface and provide a tooth for the new paint. Don't cut through to the vinyl surface.

HOW-TO: Repainting Plastic Body Parts

5. A hardener additive like Ditzler's DXR-80 is used with acrylic enamel to provide a catalyst action, reduce curing time and increase the gloss.

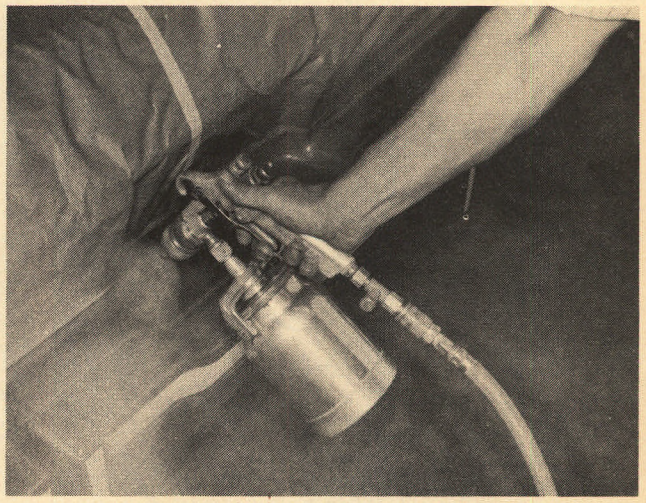
6. Now the acrylic enamel is strained into the spray gun cup. Don't fill it more than ¾ full, as there's another additive to follow.

7. As we're using Ditzler products here, the accelerator additive is DXR-81. Quick drying is necessary, as you don't want the paint to sink into the vinyl too far.



8. Once the paint and additives are mixed, bring the air pressure up and spray a light, even color coat to finish the job. Acrylic enamel is easy with the additives.

9. Acrylic lacquer calls for the use of a plastic bond coat such as Grand-Tite. This is used just as it comes from the can—don't thin or color it.



10. Spray a light coat of the bonding agent, let it flash for at least 60 secs. and then shoot the color coat. If too much time elapses between the two, you have problems.

Accessory Fix-it Tips

A car that doesn't have any of its accessories working is not much of a car. When the windshield wipers, the air conditioning, the heater, horns, or the cigarette lighter don't work, you really only have part of an automobile. A little knowledge of the weak points in accessory units will give you a pretty good clue as to where to look and what is required to fix them. In most cases, you can even fix them yourself.

There's one accessory, however, that you should not attempt to fix, because it can be dangerous. That is the air-conditioning unit. The liquid contained in an air-conditioning system can cause severe frostbite if it splashes on your skin; and if it hits you in the eye, it can freeze the eyeball and cause blindness. You can see why we don't recommend that you play around with your air-conditioning system, but it would be a good idea if you knew how it worked and perhaps were able to do a certain amount of diagnosis that you could pass on to the air-conditioning serviceman you choose to do the repairs. So let's take a look at air conditioning first.

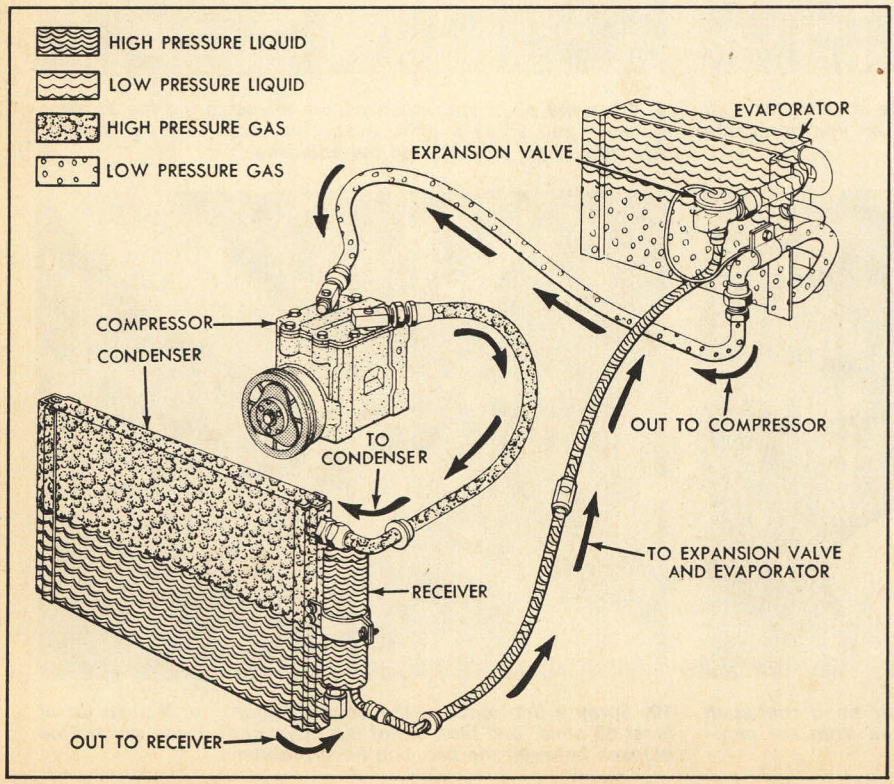
AIR CONDITIONING

Nobody really knows how an air conditioner works; it works according to laws of nature. Water boils at 212° F., just because it does. It's one of those things that you can't explain, you just have to accept. The theory of air conditioning is based on a similar law of nature. You must accept the fact that when a substance evaporates—which, of course, means changing from a liquid to a gaseous state—it absorbs heat. Another way of stating this is that it takes a certain amount of heat to make a substance go from the liquid to the gaseous state. Either way you look at it, whenever a liquid evaporates and becomes a gas, a certain amount of heat is necessary to do the job. Pour some water on your hand and your skin will feel cool. It's because the water evaporates into the air, and in so doing, absorbs heat from your hand. Do it with alcohol and you will find that your skin becomes quite a bit cooler than with water. It's because the alcohol absorbs more heat when changing from a liquid to a gas.

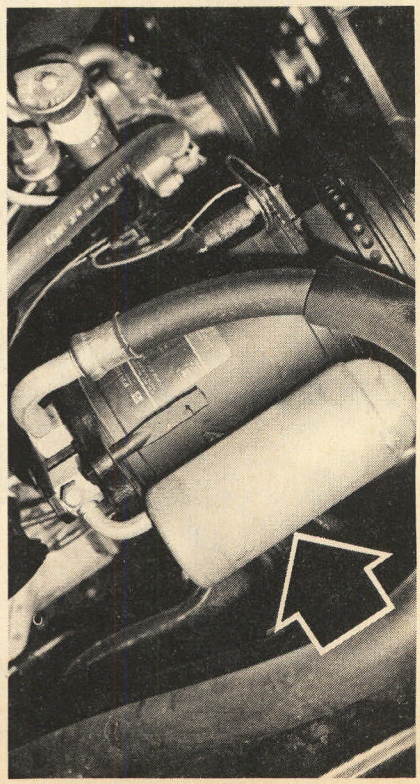
If the absorption of heat will change a substance from liquid to gas, then it's reasonable to assume that if the substance gives up heat, it will change from a gas back to a liquid. About this time you should be getting a glimmer of how the air-conditioning system in your car works. All you need is some kind of liquid that you can evaporate in the passenger compartment. The liquid will, of course, pick up heat when it evaporates, thus cooling the air around the passengers. Then if you take the gas that results and cool it enough by blowing air over it so that it condenses back to a liquid, you have completed a full air-conditioning cycle and you can start all over again with the same liquid, evaporating it in the passenger compartment to cool the air.

The marvelous liquid that is used in an air-conditioning system to do this terrific job is called Refrigerant 12 or R-12. You have probably heard it referred to as Freon. Strictly speaking, Freon is only the trade name of the Refrigerant 12 that is sold by DuPont.

If you have the cycle of evaporation and condensation firmly in your mind—that the R-12 absorbs heat when it evaporates and gives off heat when it condenses—then we can take a look at the mechanical components of the air-conditioning system and see how they make the R-12 do its work. The R-12 is circulated through the air-conditioning system by the compressor that is mounted on the engine and driven by a belt from the engine crankshaft. You won't



1. Typical Air-Conditioning System



2. Muffler on Olds Compressor

have any trouble recognizing the compressor on an engine. Just lift the hood and look for the biggest and ugliest hunk of iron that you can find.

The easiest way to understand the compressor is to consider it nothing more or less than a simple pump. From the compressor, the R-12 is pumped to the condenser, which is usually mounted in front of the radiator. From the condenser, the R-12 goes to the receiver-dryer, then to the expansion valve which controls the flow, then to the evaporator and back to the compressor. The evaporator is in the passenger compartment, of course, because that is where we want the R-12 to absorb heat when it evaporates. The condenser is out in front of the radiator in the main airflow, because we want it in the coolest place we can find, so that the R-12 can get rid of the heat.

When the R-12 comes out of the evaporator, it is a gas and it goes from there directly to the compressor. Therefore, the compressor is pumping gas only. It compresses the gas and forces it into the condenser, where the gas gives up heat to the air that is flowing through the condenser fins. With this release of heat, the gas condenses to a liquid and flows to the receiver-dryer, the expansion valve, and into the evaporator again.

1. The refrigerant, called R-12, in a typical air-conditioning system is constantly changing from a liquid to a gas and back again under conditions of high and low pressure.

2. The large silver canister beside the compressor on this '72 Olds is a muffler. It helps cut down noises from the compressor and also helps minimize line vibrations.

3. Old-style GM compressor, with the piston rods connecting the socket plate to the pistons. Later models have longer pistons, without rods.

The expansion valve is necessary because there must be some way of controlling the flow of liquid into the evaporator. Without the control, liquid R-12 could flow through the evaporator faster than it could change from a liquid to a gas. The expansion valve controls the flow by sensing the temperature of the R-12 as it leaves the evaporator. A sensing bulb, connected to the expansion valve with a capillary tube, tells the expansion valve when to open and when to close. If the gas flowing out of the evaporator coil is too hot, the expansion valve will open and allow more R-12 to come in. If the gas is too cold, it means that the R-12 is flowing through so fast that it can't pick up the heat. In that case, the expansion valve cuts down the rate of flow.

If the expansion valve goes bad and allows liquid R-12 to flow out of the evaporator and get into the compressor, it can really ruin things. A liquid is not compressible, but the compressor does not know this and will try to compress it anyway. The result can be a mess and very expensive to fix.

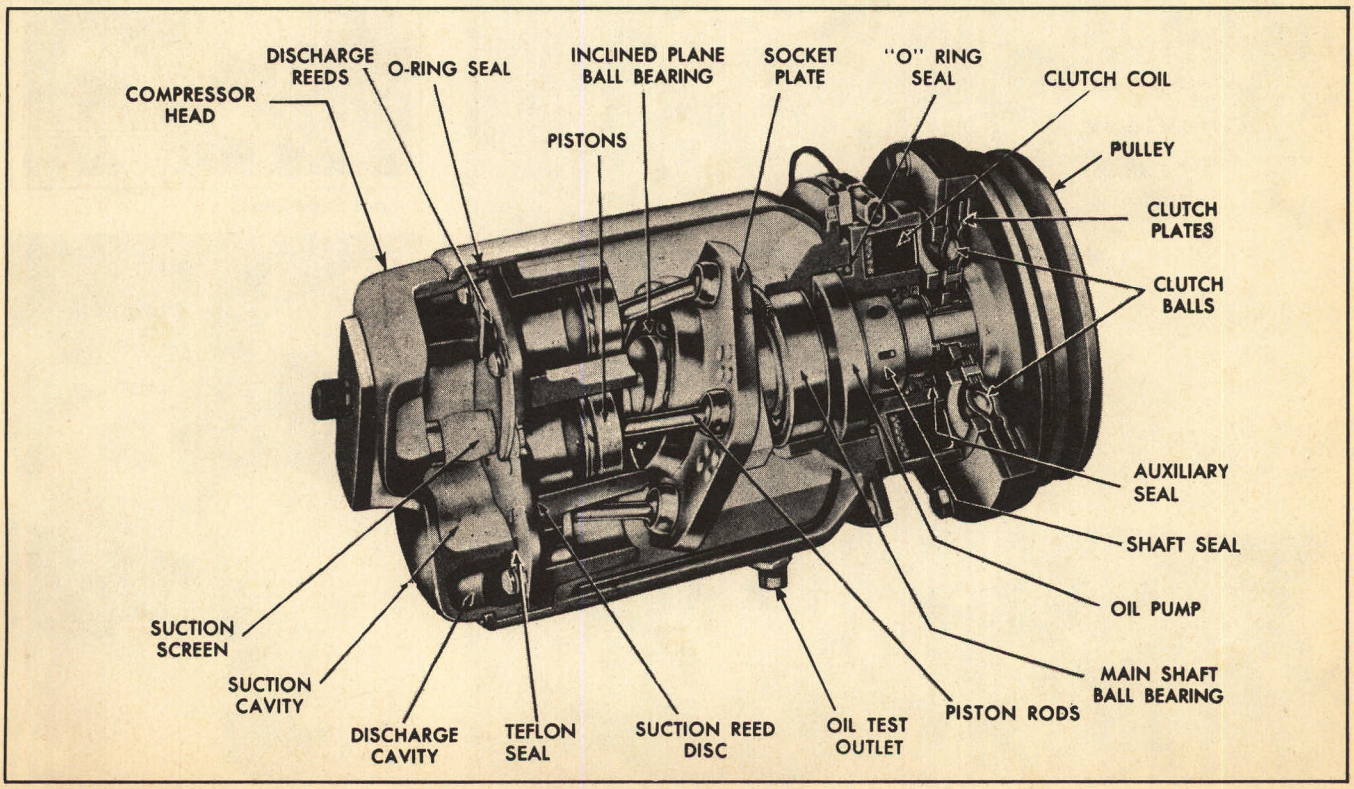
When the expansion valve cuts down on the flow of liquid R-12, there has to be some place for the liquid to go, because the compressor is pumping continuously. This is where the receiver-dryer comes in. It is mounted between the condenser and the expansion valve. The receiver-dryer is a small tank with an inlet at the top and the outlet attached to a dip tube that goes to the bottom. When the expansion valve allows a lot of R-12 to pass, the level of liquid R-12 in the receiver-dryer goes down. The space that was taken up by the liquid is now filled with gas. This situation occurs because the condenser cannot condense the gas into a liquid fast enough when the flow is too great.

The receiver-dryer takes care of the situation very well, however. When the expansion valve slows down the flow, the condenser will do its job better, and the gas in the receiver-dryer will be displaced by liquid R-12.

The basic air-conditioning system is really very simple. The controls that are added to the basic system to make it work better are where we run into some complication. Our air-conditioning units today use a clutch on the compressor pulley to turn the compressor on and off. The belt from the engine drives the pulley at all times, but the clutch is magnetically actuated so that it can engage or disengage the pulley from the compressor shaft. Occasionally the clutch plate will develop slippage—it moves into position when actuated and engages the pulley, but the pulley cannot drive it.

Some air-conditioning units use what is known as the clutch cycling method to control temperature. If the temperature gets too cold, they disengage the magnetic clutch so that the compressor shuts down. Of course, this stops the flow of R-12 so that nothing happens anymore. Other manufacturers leave the compressor clutch engaged anytime the air-conditioning unit is on. They control the flow of R-12 with additional valves that sense temperature and allow the R-12 to double back from the pressure to the suction side of the compressor.

The situation really gets complicated when the heater is hooked to the system for completely automatic temperature control. Those units will turn either the heater or air conditioner on or off when-



3. GM Compressor

Accessory Fix-it Tips

ever necessary to control the temperature in the car without any need for the driver to do anything except set the temperature he wants to maintain.

In checking out an air-conditioning system, the first thing to do is to have the engine running and observe the compressor while someone inside the car turns the air conditioner on and off. You should be able to see the compressor engage and disengage the pulley from the compressor shaft. If the compressor is working, look for the sight glass which is either on top of the receiver-dryer or in the line leading to it. The sight glass will probably be so covered with dust and dirt that you can't see anything. Wipe it off and observe the flow of liquid refrigerant.

Don't worry about any bubbles that appear when the compressor is first started; they should go away as the system gets operating. In fact, bubbles in the sight glass do not always indicate a low refrigerant level in the system. If the system is at a control point, bubbles may appear even when it's fully charged. A certain amount of foaming is also normal if the outside air temperature is 70°F or below. But if you do see bubbles in the sight glass, and they continue after the system has been in operation for several minutes, head for an air-conditioner service outlet and have it checked out—odds are that you will need an R-12 recharge and perhaps even repairs for minor leaks.

A system that is low on refrigerant does not necessarily mean that a leak has to be fixed somewhere. If you have to have the system charged once every five years, then it would be silly to look for such a minor leak. However, if every three months the system is bad because the refrigerant is leaking out, then you had better get your serviceman to find the leak or you might as well plan on doing a lot of recharging. Sometimes, the system works no better after servicing. In this case, it's likely that dirt, air, or moisture were allowed to get into the lines. As efficient air conditioner operation depends upon the pressure/temperature relationship of pure R-12, any contamination introduced alters this relationship and the system cannot function properly.

The electrical part of the air-conditioning system is the easiest to fix. If you don't get any air coming through the evaporator, look for a blower fuse that is burned out. It could even be a bad blower switch. If the compressor is not working, check for a blown fuse near the compressor on top of the engine. A check of a wiring diagram for your air-conditioning system will help you to locate fuses. The wiring diagram can be found in the shop manual for your car.

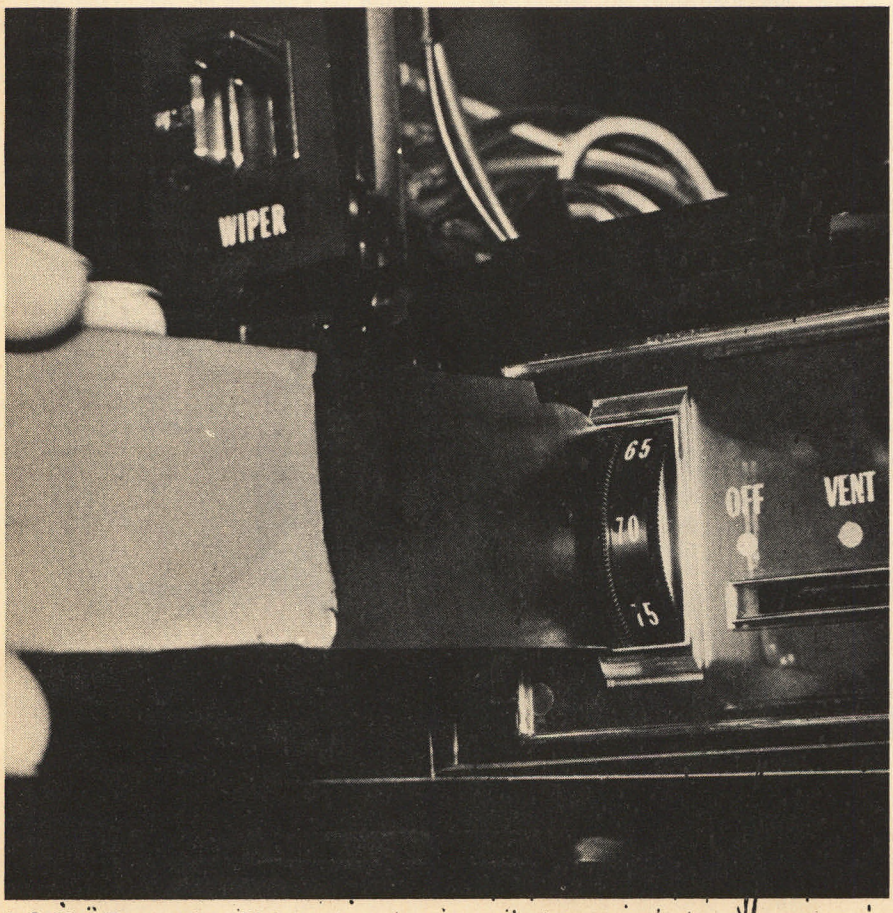
Many times a case of low cooling is not the fault of the air conditioner at all. Most cars have many air ducts or places where outside air can leak in. A leak in any location will allow hot outside air to enter, so that no matter how hard the air conditioner works, it can't keep up. To find leaks, drive at freeway speeds and have a friend put his hand in front of all the ducts and possible leaks. Fixing the leaks with tape is no problem, once you have located them.

CLOCK

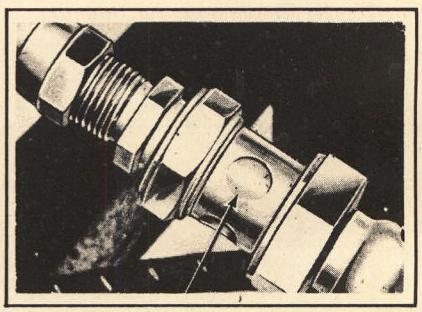
Practically all modern automobile clocks are of the electrically wound, mechanical type. Late models are equipped with an adjustment feature that speeds up or slows down the clock whenever the time is reset by hand. Earlier models have an adjustment lever which can be moved slightly in the direction of "S" or "F". After a few such adjustments the clock should maintain reasonably accurate time.

Automotive clocks have been unfairly accused of being the most unreliable part of the car. We say "unfairly" because while no one seems to question the wisdom of taking his wristwatch to the jeweler once a year for a routine cleaning, equivalent care is rarely given the clock in a car. The lubricant in the mechanism has the same tendency to form gum after long periods, and the unit is subjected to road shocks and extremes of temperature. Thus, the automobile clock should be given routine service like any other timepiece.

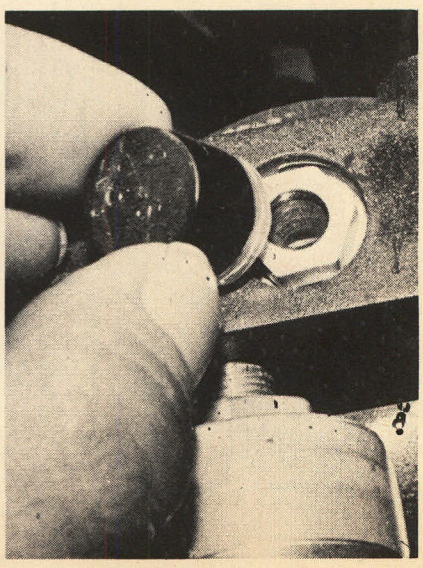
The clock is always connected to the "hot" side of the ignition switch so that there is a current source for the winding mechanism whether the car is in use or not. If the unit is remote from the instrument cluster, there will be another wire leading from the illuminating bulb in the clock to the main light switch. Both of these circuits are grounded through the screws attaching the clock case to the



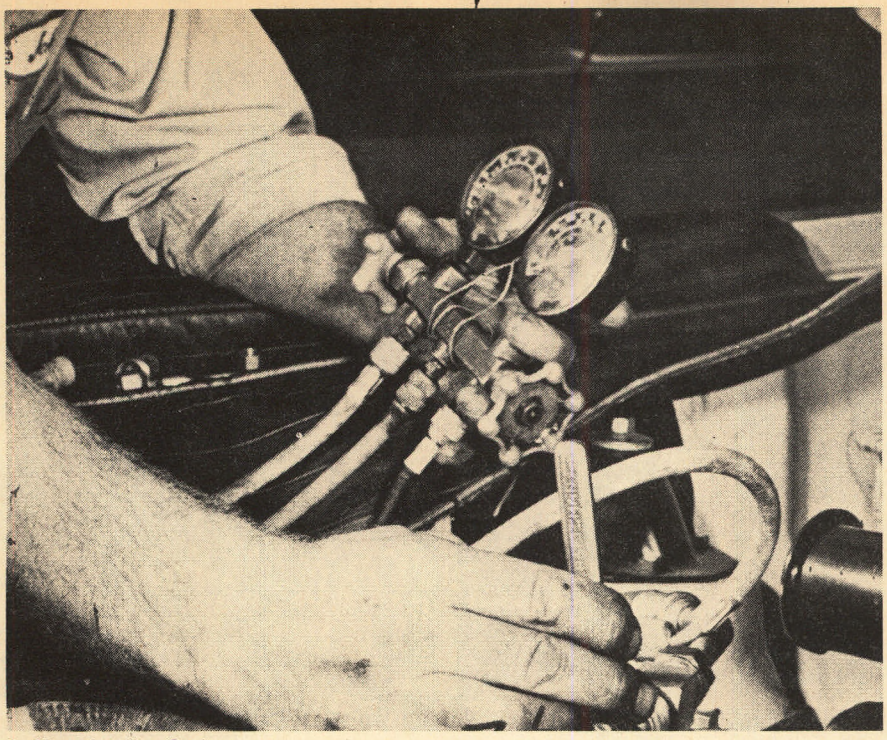
1. Setting Temperature Dial



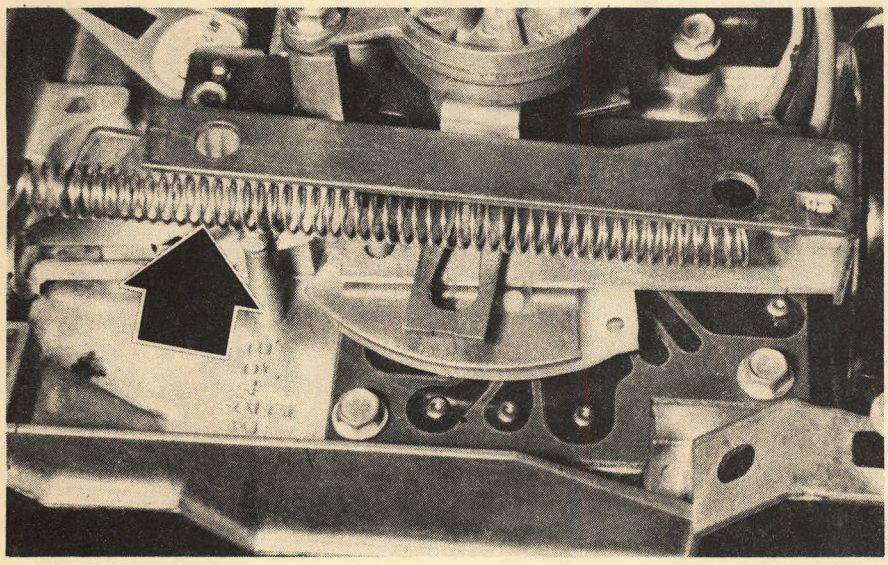
2. Ford Sight Glass



3. Dust Cap on Plymouth Sight Glass



4. Charging the System



5. Printed Circuit Switch

1. Setting the temperature control dial on a GM Climate Control is done with a special tool that holds the shaft while you turn the dial.

2. Ford sight glass is in the line, instead of being on top of the dryer-receiver. A continuous stream of bubbles in the sight glass indicates the system needs a charge.

3. The sight glass on most cars gets covered with dirt in time, so you'll have to clean it off to check for bubbles in the system. This Plymouth, though, has a dust cap.

4. Your air-conditioning system can be recharged at any garage that does a.c. work. A checkout of the system and an R-12 recharge costs $10-$15.

5. Late-model Buicks have a printed circuit switch, controlled by a vacuum diaphragm working against a long spring (arrow).

panel so if the clock is inoperative, the tightness of these screws is the first item to check. The clock may be removed for repairs by unfastening these screws and the connecting wires. If the clock is part of the instrument cluster itself, the entire cluster must usually be removed to gain access to the clock. Some of the more modern clusters have printed or "bread board" circuitry, and the electrical connections are automatically made when the clock is positioned correctly in its mounting.

Generally speaking, two things can go wrong with an automotive clock. Either the clock movement stops operating, or the winding mechanism gets gummed up so that it doesn't work and blows a fuse. When you put a new fuse in, it will blow immediately. This is usually caused by a lack of lubrication or a gumming of the old lubrication in the winding mechanism. To fix the winding mechanism you will have to take the clock housing itself apart, but it is not necessary to do anything to the works. A little oil in the right spot, which is obvious on inspection, and you will eliminate the fuse blowing. If it turns out that the clock problem is in the works itself, take it to a watchmaker so you can get professional repairs.

AUTOMATIC SPEED CONTROL

In a typical system, the desired speed is dialed on a gauge, sometimes incorporated in the speedometer. When the driver wishes this speed to be automatically maintained, he pushes the "speed set" button located in the tip of the turn indicator control on some cars. The unit will maintain this speed regardless of terrain, adding to or cutting back on the throttle opening automatically as is required. However, it has no way of telling that you are bearing down on a slow truck or coming up on an intersection. This information you feed into it by stepping lightly or otherwise on the brake. This action, sensed by an electro-vacuum switch in the system, deactivates the control until such time as you twirl the "resume-speed" switch.

Some older systems do not have the "resume-speed" switch. These return the car to automatic control as soon as the driver brings the vehicle back to the preselected speed. The tell-tale sign that the control has taken over is a pronounced stiffening of the accelerator pedal. You can override this to go faster, though the pressure on the pedal required is uncomfortable for any period longer than passing another car, but you cannot override it to go slower unless you de-activate the system with the brake.

Due to the safety hazard that could be created by any error in the adjustment or repair of a component in an automatic speed control system, it is recommended that this system be serviced only by a factory-trained mechanic.

AUTOMATIC HEADLIGHT DIMMERS

Headlight dimmers used to be very obvious. The photocell setup was on the top of the dash behind the windshield and looked very much like a gunsight or aiming device for the car. Late models all have the photo tube mounted in the grille or leading edge of the fender. It's not as prominent in that position but it is much more susceptible to dust and road grime. Many problems with the headlight dimmer can be solved simply by wiping off the front of the photocell.

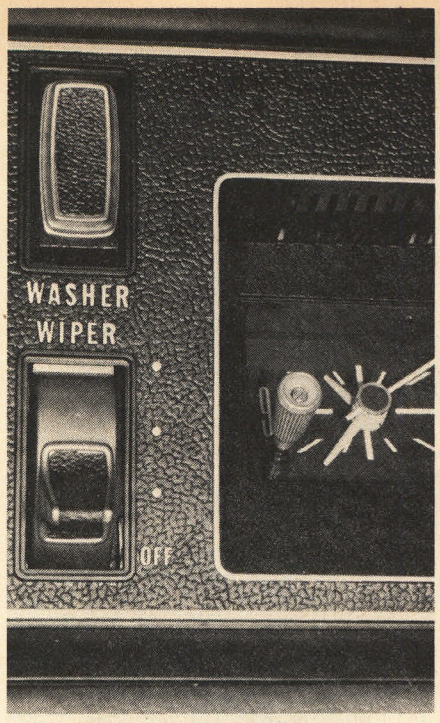
Some cars have an on-off control in the headlight switch but in most models the only control is the foot-operated dimmer switch. One position of the dimmer switch puts the headlight control on automatic. The other position will keep the headlights on low beam at all times. There is a third position built into the foot switch which allows the driver to override the control and obtain high beam in bright areas or during daylight. This third position is activated by depressing the foot switch just until resistance is felt. When the driver takes his foot off

the switch, the headlights will go back to low beam.

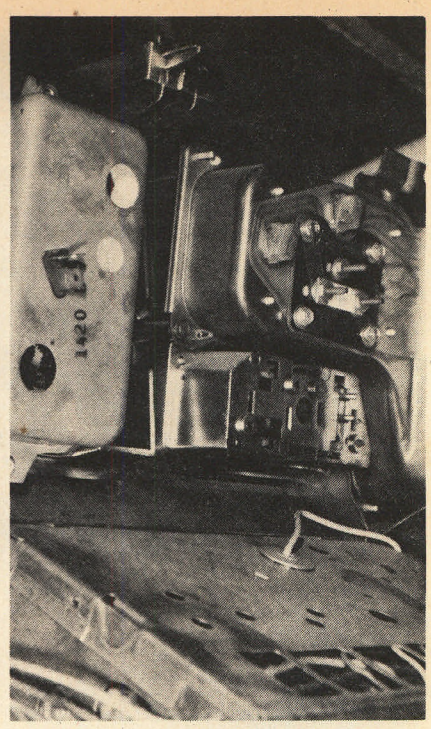
The system consists of a photo-electric cell and amplifier, usually housed as one unit on top of the instrument panel or on the left front fender; a power relay; a manual override foot switch to replace the conventional dimmer; and the vernier switch that lets the driver adjust sensitivity within the limits of the basic factory-set calibration. Horizontal aim on most dash-mounted models may be adjusted by turning the pivot pin accessible on the outside of the case. The unit should be aimed as parallel as is visually possible to the centerline of the car. Vertical aiming requires removal of the case, which on some models will expose a bubble-type leveling gauge built into the sensing unit. While aiming vertically, the car must be on an absolutely level surface, the tires inflated properly and no load other than a half tank of gas.

HEATER/DEFROSTER

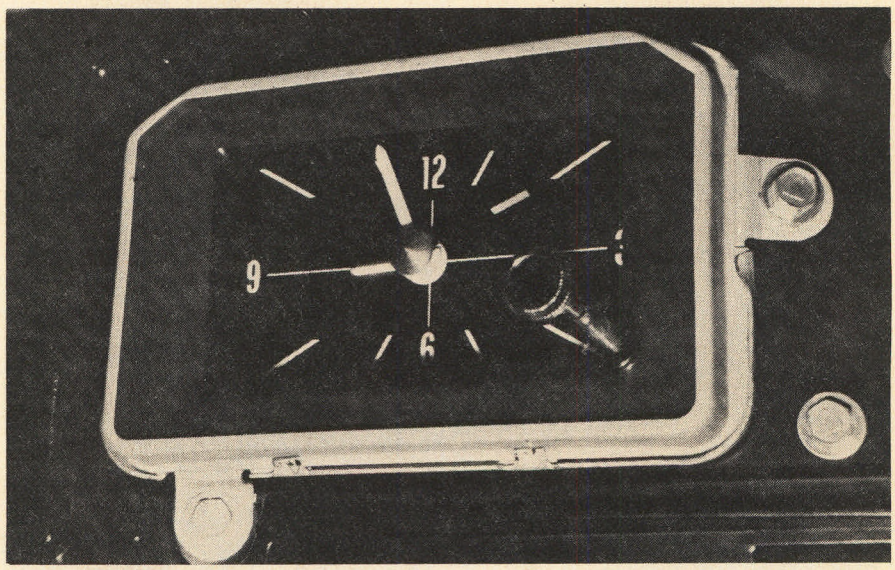
Basic differences in the design of relatively modern heaters and their associated defroster units are limited to the point of air intake and whether the various controls are actuated mechanically or by vacuum. All except those used on air-cooled cars utilize a core (basically a miniature radiator) to extract heat from the engine coolant and a fan to distribute the heated air through ducts. The most desirable but more expensive location for the fresh-air inlet is in the top surface of the cowl just forward of the windshield. The alternate location just behind the right side of the grille is bad in heavy traffic because it picks up carbon monoxide and other noxious fumes from the car ahead. Though more expensive, vacuum-actuated controls are preferable to mechanical because their action is more precise and there is considerably less linkage to get out of adjustment.



1. Typical Rear-Mounted Clock



2. '70 Buick Clock Unit



3. Front-Mounted Clock

1. Getting at the clock's attaching screws will probably be the hardest part of removing your clock. On this late Chrysler, like most cars, the time spindle comes out the front, while the clock comes out from the back of the instrument panel.

2. Repair or replacement of most clocks on late-model cars requires that you pull the entire dash. To replace this '70 Buick clock unit, many dealers will charge the equivalent of 4 hrs. labor. For '73 Buick has gone back to the front-mounted clock removed by prying loose the trim panel that surrounds it.

3. Check your factory service manual before attempting this, but on older cars the clock's attaching screws often are exposed at the front of the dash once the dash trim is removed.

4. Cars with sporty interiors like Mustang and Cougar often have the clock mounted down on the console, which makes getting at the clock a little easier than working behind a cramped dashboard.

5. The brake switch and vacuum lines are important parts in an automatic speed control system. Malfunctions in these components can cause a runaway!

HEATER SERVICING

Servicing any of the more modern heater/defroster designs is one of the meanest jobs (perhaps second only to windshield wiper linkage) on the car, helped in only a few rare instances where the blower motor and fan are accessible through the engine side of the cowl. Fortunately, very little will go wrong with the heater/defroster system.

There are two ways of controlling the heat: with a water valve or air doors. A water valve usually has a thermostat built into it. When you move the control valve to "Hot," you are doing nothing more than turning up the thermostat. In the air-door system, water flows through the heater core at all times, and the doors direct the air either through or around the heater, or both, in varying degrees. There is usually no thermostat in this system. You set the doors where you want them to get the right amount of heat.

Assuming the blower motor is working, heater malfunctions generally fall into these categories: 1) no heat, 2) heat all the time, and 3) not enough heat. Let's deal with the latter symptom first because it is frequently caused by malfunction outside of the system or even unfamiliarity on the part of the operator. Cable-actuated heating systems are found on most compact and intermediate-size cars. The somewhat more elaborate vacuum-actuated system is used on more expensive cars.

In the cable-controlled model, a lever control actuates the air door in the ductwork to direct the airflow almost entirely to the interior of the car or almost entirely to the defroster outlets. The position marked "Heat" usually routes 80% of the heated air to the interior and 20% to the

defroster outlets. Another lever controls the degree of heat, from none to maximum, by actuating another door in the ductwork which determines how much of the incoming air is routed through the heater coil. A multi-position switch determines the speed of the fan. The fan is necessary in traffic but at highway speeds there is a ram effect from the incoming air and operation of the fan is no longer necessary.

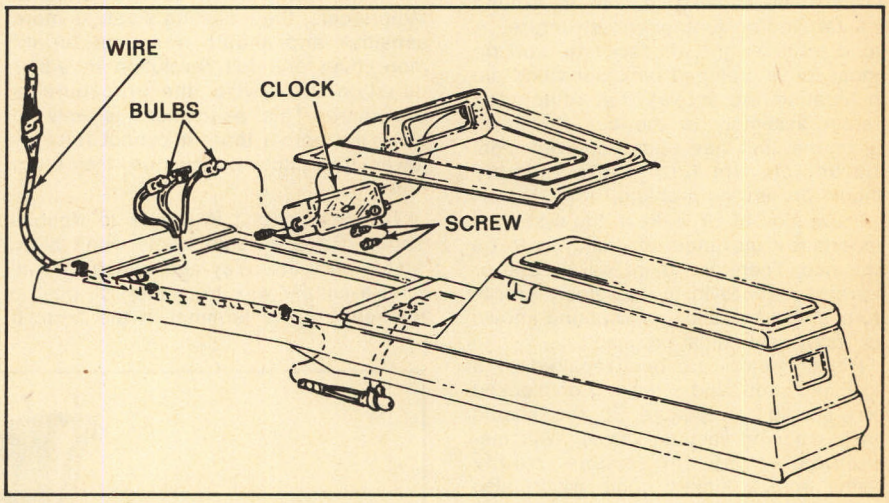
Thus, the basics in operating this type of heater are deciding how you want to divide the incoming air, how hot it should be, and whether or not it needs a boost from the fan. Fresh-air ventilation is handled manually on either side, usually by direct controls mounted in the kickpads or under each side of the instrument panel. These outlets should not be used when heated air is desired. As to windows, you have to experiment with them or consult the operator's manual.

The vacuum control system works the same way except that you can't alter the heater-to-defroster airflow ratio of 80-20 or vice versa. The fresh-air vents are controlled by pushbutton and in most cases only one button may be operational at a time. The heat control and fan-speed selector are common to both systems. If pushbuttons are not present, check whether your system is vacuum or mechanical by looking for a vacuum line leading from the intake manifold to the general area of the heater. Make sure this line is free of cracks and securely seated on its nipples at both ends.

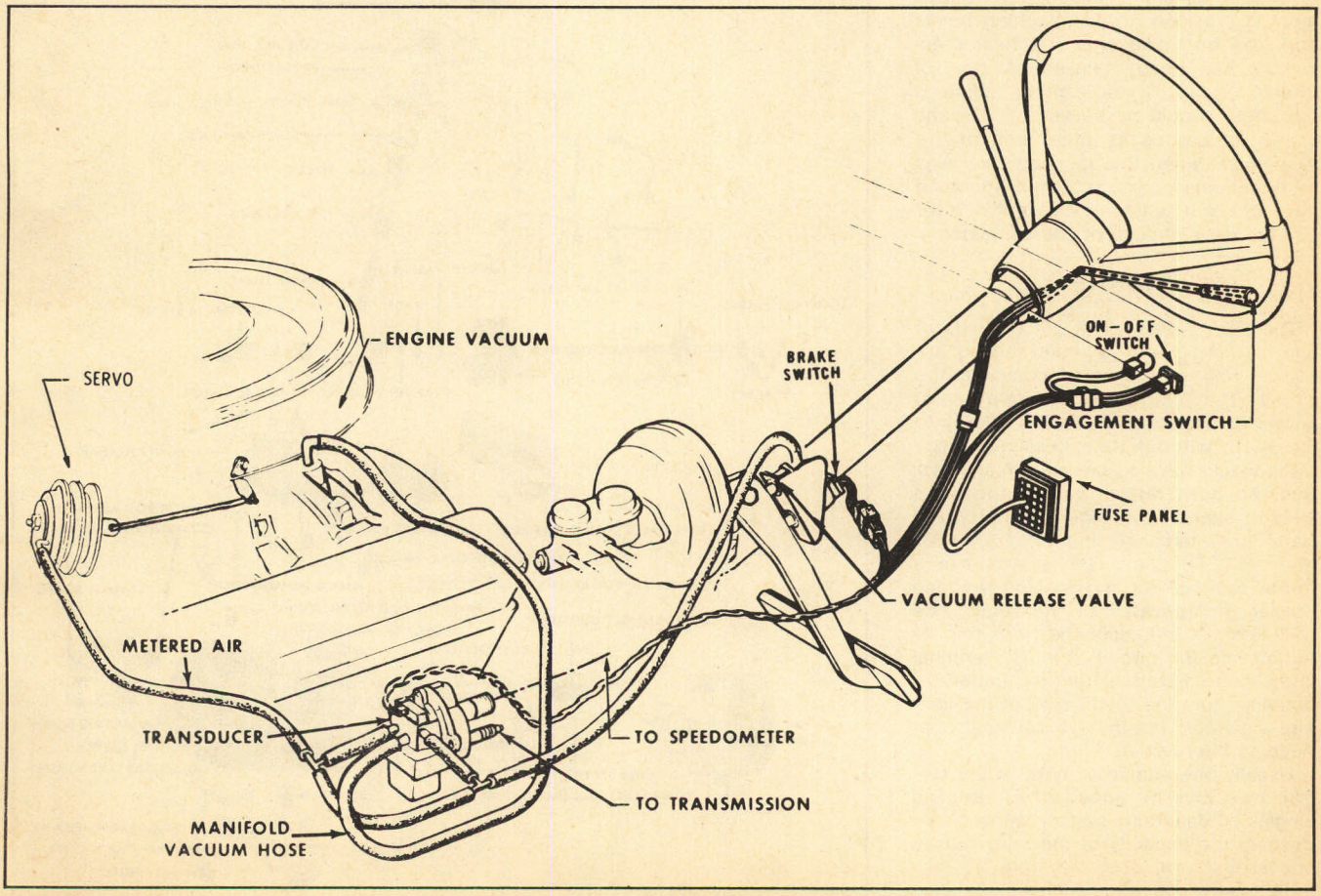
If it's not operation of the controls that is causing the problem, it may be the thermostat or water pump in the cooling system. A thermostat stuck open will result in little heat from the heating system and little heat in the engine. Double-check this, plus your knowledge of the system's operational controls, before troubleshooting.

If the vacuum or mechanical valve that controls the flow of coolant through the heater coil is sticking in a partial or fully open position, the symptom is a constant flow of heat from the heater outlets. Conversely, if it is stuck closed, no heat can be obtained. A malfunction of the mechanical type of valve will almost always evidence itself in the form of stiff, non-positive control operation. The operation of a vacuum valve is generally audible. You can turn off the engine to check its operation because there should be enough vacuum in reserve for one cycle. If you don't hear it click into position, suspect the valve. If the air-door valve is sticking open, there will be a flow of cold air from the heater or defroster outlets when the heater is turned off. If it is sticking in a partially or fully closed position, little or no heat will result. Symptoms of these valves sticking are the same as described above for both types of controls.

Unfortunately, replacement of either valve usually requires removal and disas-



4. Console Clock



5. Oldsmobile Cruise Control

sembly of the entire heater. Except for noting that the engine coolant should first be drained below the level of the heater, it is impractical to give step-by-step procedures for removal of the heater due to the fact that the design for each make and model of car is different. You must first remove obvious obstructions such as the radio (see section in this chapter) and glove compartment box. Wires and cable leading to the system should be disconnected, and also the hoses at their attaching point on the engine side of the cowl. Note that in addition to the power lead to the fan, there will also be a separate wire to ground the fan motor to the car structure. A good trouble light will facilitate working under these cramped conditions and aid in locating the screws that attach the heater assembly to the car structure. Once the unit has been removed from the vehicle, its further disassembly should present no problem.

Prevention of air leaks in the system is important if maximum efficiency is to be obtained. Therefore, there will be one or more sequences in the assembly procedure where a caulking compound known as "body seal" must be used.

Heater motors are best repaired by a specialty shop, and a leaking or blocked core should be replaced. So, too, should malfunctioning vacuum valves. With mechanical valves, the trouble usually stems from a kinked cable which also must be replaced. Attempts to "unkink" these are usually unsuccessful. Adjustment is provided at the attaching points and may be made after the heater assembly has been installed. A rule of thumb for mechanical control action is that there should be between 1/16- and 1/8-in. clearance at either end of the lever travel when the applicable valve is in its extreme positions. When attaching the cable, the setting of the control lever and the valve should, of course, match.

HORNS

The horn system on a car consists of one or more horns, a relay and an actuating ring or button to complete the circuit. The function of the relay is to deliver a full ration of electric energy to the horn; without it, excessively large wires would have to be used in the system. All horn relays, except those on 1968 or later model General Motors cars, have three terminals marked "S," "B," and "H." The new GM relays have a fourth terminal for the ignition warning buzzer incorporated in the relay. The "S" terminal connects the horn ring or button into the circuit; the "B" terminal is the current source from the battery or actually, from the "hot" side of the voltage regulator; and the "H" terminal connects to the horn.

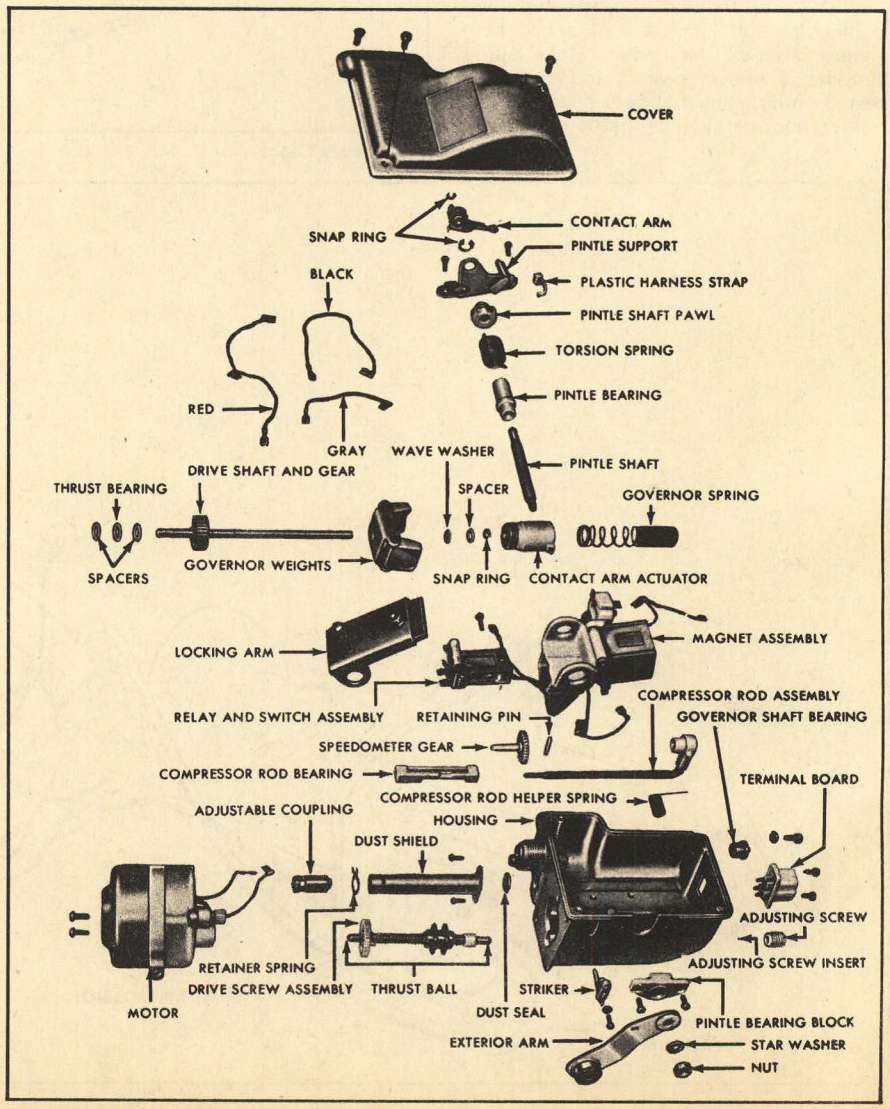
Usually one additional horn of the factory type may be added to an existing single- or dual-horn system without exceeding the capacity of the relay but an accessory horn, operated from its own switch, must be equipped with its own relay. The circuit is grounded through the horn mountings and at the steering wheel column. When the horn button or ring is pushed, it grounds or completes the circuit, the electromagnet in the relay is energized and makes contact, and the horns blow. When the circuit is not energized, a spring on the electromagnet keeps the contact open.

A horn with a harsh or tinny sound may only need adjustment. The method of adjustment varies by make. In the Sparton, Autolite and Prestolite horns used on Ford, American Motors and Chrysler cars, the adjusting screw or nut should be turned counterclockwise until no tone is heard. Then the adjustment is turned clockwise, ¼-turn at a time, until the desired mellow sound is achieved. In the Delco-Remy horns used on General Motors cars, the adjusting screw is more sensitive and should never be turned more than one full revolution in either direction. Otherwise, the procedure is the same. This adjustment is only to clear the horn's tone; it cannot raise or lower the pitch or change the basic note.

The horn circuit is simple to trouble-shoot. If one or both horns won't blow, first bypass the relay and switch by running a jumper wire from the "B" post in the relay to the terminal in the horn. If the horn then blows, the trouble lies in the relay or switch. If the horn doesn't blow, try tapping it—dirt may have lodged in the contact. If it blows only when tapped, it may be badly out of adjustment and the procedures described above should be followed.

On older cars, the no-blow problem is usually caused by a bad ground from rust under the horn mounting. Cleaning the rust away until you get a bright metal mounting won't always cure it, either, because the fender panel that the horn is mounted to might have its own bad ground from rust. A quick way to find out if the horn is any good at all is to run a ground wire from the body of the horn back to the ground battery post. If the horn works, you know you have a ground problem and some cleanup work to do.

A faulty horn is easier to replace than to repair, but before this, isolate the relay from the switch. Connect the jumper wire from the "B" terminal to the "H" terminal. If the horn blows, the relay is defective and should be replaced. To check the switch on the steering wheel with a relay that is known to be functioning, run the jumper wire from the "S" terminal to ground. If the horns blow, the

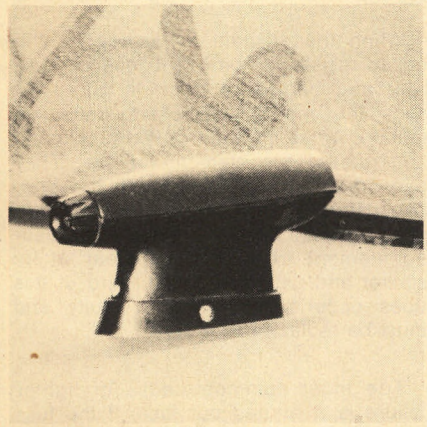


1. Speed Control Servo Unit

1. We doubt you'll ever take one apart, but this shows how control is designed. This is a late GM type. Note governor weights (center) that maintain throttle opening once the system has been set.

2. Older GM system had phototube mounted above dash like gunsight.

3. Later GM models mount the tube behind the grille. The system often is combined with sentinel system that turns the headlights off.



2. Early-Model Headlight Dimmer

switch should be checked for dirt or faulty connections at the horn ring. Most rings may be removed by turning the decorative center plate to the left and removing it. This exposes the attaching screws for the ring which in turn may be removed for access to the switch. Switches, also, are easier to replace than repair.

ACCESSORY HORNS

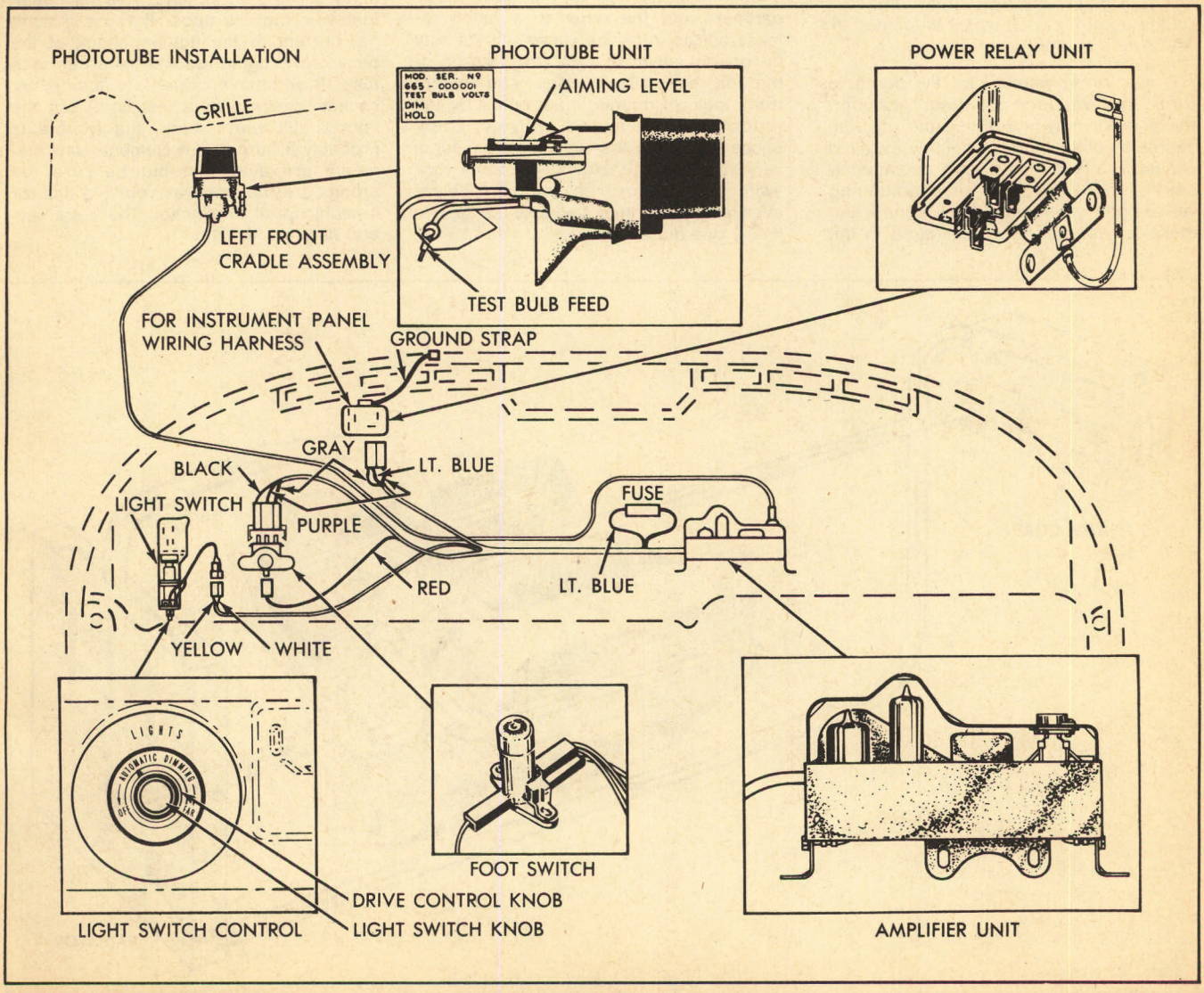
There is a wide variety of accessory horns on the market, ranging from genuine, truck-type units actuated by compressed air to novelties that imitate such sounds as Bermuda bells and a mustang's whinny. The true compressed-air installation is relatively expensive as it requires a belt-driven compressor, smaller but similar to the ones used in air-conditioning systems. Somewhat cheaper are the electrically actuated compressors (or vacuum pumps, depending on the system), but some are a little short on power and consequently the note may be a rather poor imitation of the real thing. Still other accessory installations are operated by cylinders of compressed gas which must be replaced periodically. The latter two types are relatively easy to install as the system is completely separate from the standard factory installation. Mail order houses like J. C. Whitney and Vilem B. Haan list all types of horns and the units come with complete installation instructions.

One particular type should be purchased with caution. This imitates the standard European "hee-haw" emergency signal which is now being adopted by some American police, fire, and ambulance operations. Any horn on a passenger car that even resembles an emergency warning is illegal in all states. A louder than normal sound, however, usually is not.

LOCKS

If you have to replace an ignition key lock or door lock, it's best to avoid buying a replacement lock cylinder that is already coded because you'll end up with the nuisance of a different set of keys for each lock. A locksmith can sometimes adapt a key to work in both the old and the new lock, but this makes them a lot less pick-proof. The best method is to buy an uncoded replacement cylinder and have the locksmith file the tumblers to fit the existing key.

A door lock is easy to remove and replace once access to it is gained by re-



3. Grille-Mounted Headlight Dimmer

moving the door trim panel. In practically all designs, the panel is held by a retaining clip on the inside of the door sheetmetal which can be sprung off with a screwdriver. This clip will be found there whether the lock is in the door handle or separate from it. The lock assembly then slides out of its socket or housing in the door. The replacement assembly consists of a lock cylinder and a dust cover. The latter must be crimped to hold it in place before installation in the housing. A new cylinder should be lubricated, but this may be done after the job is buttoned up simply by coating the key with a light graphite and working the lock a few times.

Trunk lock replacement is done in the same manner, speeded, of course, by the lack of upholstery in that area. The lock in the tailgate of a station wagon may be reached by removing the window molding and trim panel and manipulating the glass electrically or by crank out of the way. Exercise caution here because when the glass is fully extended in a tailgate that is open, it is free to fall out of its retaining channels in most designs. To operate an electric window with the tailgate open, press the spring ground with your finger and have a partner actuate the control switch which is located in the driver's compartment.

Power locks, whether for the doors or trunk, are vacuum actuated. Although these locks may use the same vacuum source as other more commonly installed accessory components such as vacuum-controlled heater and air-conditioning valves—and the vacuum lines connecting these accessories may be shared in the interest of economy and saving clutter—each will have its own vacuum reservoir. These are usually located under the hood on the left fender. Most designs have a separate switch, usually in the glove compartment, through which the vacuum line for the trunk lock is routed.

Except for binding in the actuating cylinder, about the only malfunction possible in these systems is a crimped or leaking vacuum supply hose. It is easy to isolate the hose involved. With the engine idling, disconnect a vacuum supply hose to an accessory known to be working, place your fingertip over the end and feel the degree of suction. Anything less than full engine vacuum in the suspected hose indicates a crimp or leak. You may locate a crimp by observing the hose throughout its length; a leak may also be located by repeating this check at each connecting point or T-fitting. A leaking hose may be temporarily taped until replacement is convenient. If all vacuum-operated accessories are malfunctioning, the leak will be between the source of supply on the intake manifold and the first reservoir in the line. Further evidence can be found in a faster than usual, loping idle.

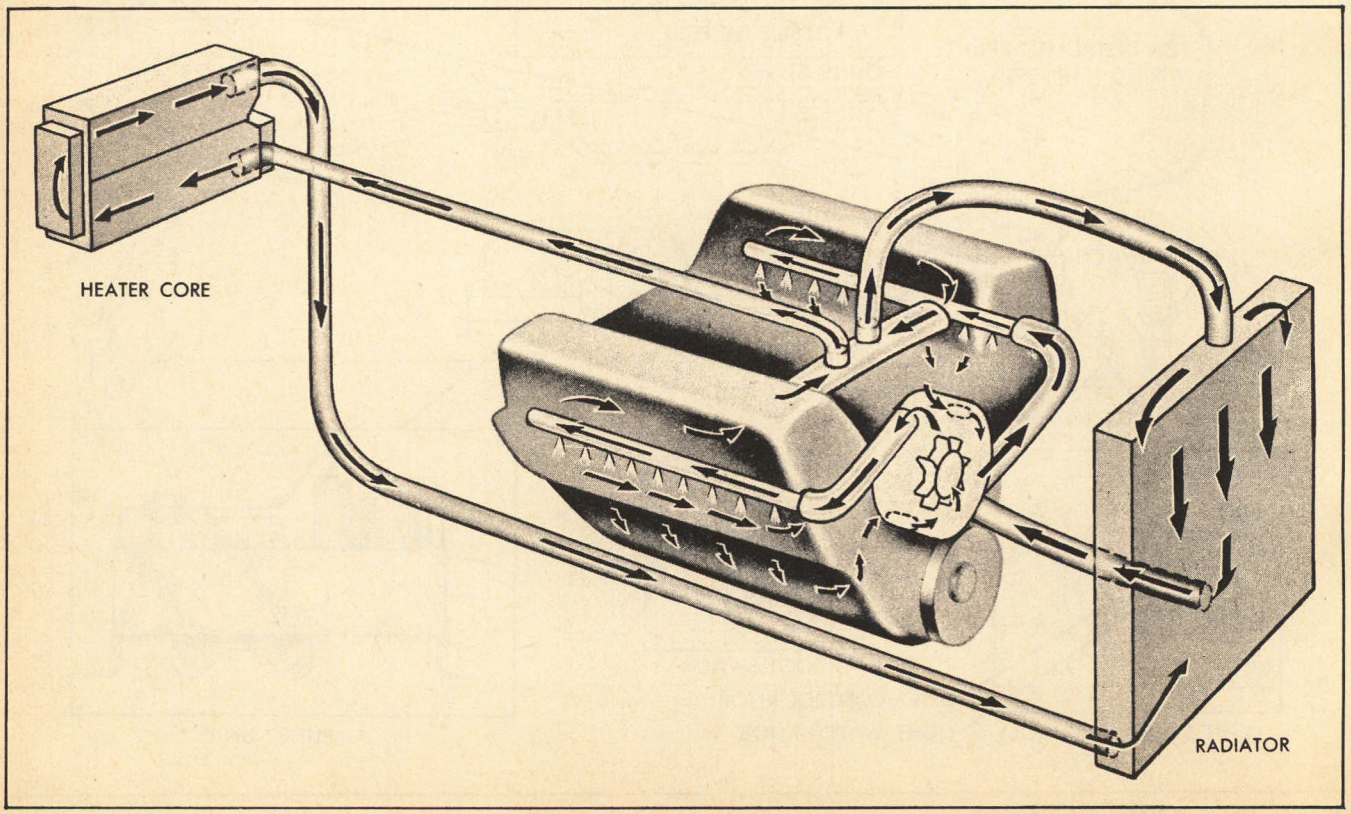
The simplest type of "power" trunk lock is a cable with one end attached to a pull knob located in the glove compartment and the other to a catch release on the trunk lid. Universal kits may be bought at most auto parts stores or through mail order houses. The regular trunk lock, of course, must either be left unlocked or removed entirely. Body shops will fill in the resulting hole for a very small charge. Hiding the trunk lock switch in the glove compartment delays even a serious thief because he has to jimmy one more lock.

CIGARETTE LIGHTER

A cigarette lighter consists of a removable element and a socket or plug. The plug is connected to the "hot" side of the ignition switch via the fuse box. In some installations, interior courtesy lights share the same 20-amp fuse, but in many designs there is a cartridge type fuse on the back of the lighter. As the plug is always "hot," it is a convenient source of power for accessories such as a trouble light, vacuum cleaner and coffee maker as well as the lighter element.

When the element is pushed in, the coiled resistance wire in it receives current and begins to heat. In 10 to 14 secs. the heat is sufficient to cause bimetallic grips in the socket to expand and release the element for use. They expand only a certain amount, however, because they also have a secondary gripping point to prevent the spring-loaded element from popping clear of its socket and causing a fire hazard. If this does occur, the socket is faulty and must be replaced as a unit.

The most common cause of lighter failure is a burned out fuse. If the fuse block has a slot marked "ltr" something similar, try putting in a new fuse that you know is good. If you still don't get current to the lighter, check at the back of the lighter socket for a cartridge fuse. If you have current to the lighter socket (check with a test light) but the lighter still won't work, the trouble is probably a burned out element. New elements are available, but be sure the prongs are the same as your old one, or it might not fit the socket. There are several different designs.



1. Coolant Circulation

RADIO

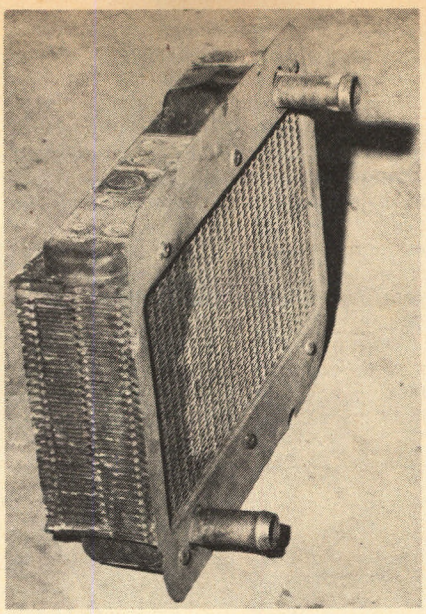
There are four basic types of radios installed in modern cars, and in recent years they have been fully transistorized. These are AM with or without pushbuttons, AM/FM, AM/FM stereo and AM incorporating a stereo tape player. Repairing any of these receivers is beyond the scope of this book, but there are many checks and adjustments which may be made on items other than the receiver that are very often the cause of the trouble. If after these checks the trouble is pinpointed to the receiver, you can remove and install it yourself and save that labor cost. Receiver repairs and particularly warranty work should be done by an authorized shop. None of the car makers builds its own radio although it will put its own name on the unit. Usually, however, the actual maker will be noted on the receiver case or you can call the car dealer and ask for the name of the authorized repair station.

A basic adjustment is antenna trimming which must be done whenever the receiver is installed after removal for repairs. The serviceman trims to his own antenna which may not have the same characteristics as the one on your car. Locations of the trimming screw vary but it is often found hidden under the tuning knob, or on the side of the radio under the instrument panel. Let the radio play for 15 mins. to warm it, set the antenna between 31 and 40 ins. and select a weak but clear station as close as possible to 1400 kc. Remove the tuning knob or otherwise expose the trimming screw. With a screwdriver turn the trimming screw in small steps in both directions to where a setting is found with the strongest signal. Replace the knob and the job is done until the next time the receiver or antenna is disturbed.

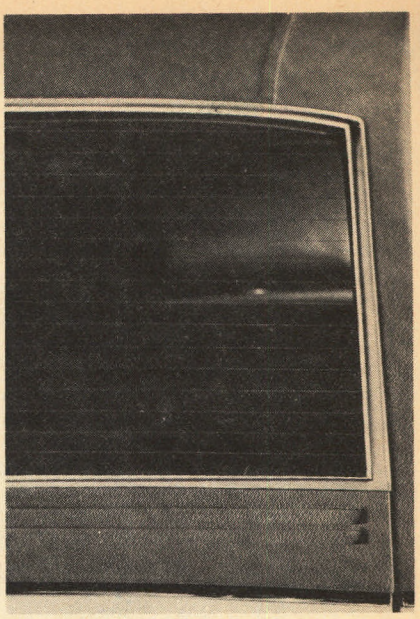
NOISE SUPPRESSORS

Capacitors to suppress radio interference are normally located at or in the alternator or generator, on the "B" terminal of the ignition coil, on the voltage regulator, on the fuse block and sometimes on certain power accessories. The connections to these may corrode or come loose, but the capacitor itself seldom "wears out." If the capacitors are suspect, but you've determined that all of their connections are tight and clean, it is cheaper from a time standpoint to replace all of them rather than to try to isolate the offending item. Before doing this, however, inspect the spark plug wires. One or more old, leaking plug wires can cause radio static very similar in sound to a defective capacitor. Then determine if the static occurs only when the car is moving. In this case, the trouble is likely caused by either the front wheels or tires. To isolate one of these from the other, drive on a smooth road and drag the brakes slightly. If the static stops, the problem is in the front wheels; if it continues, it is the tires.

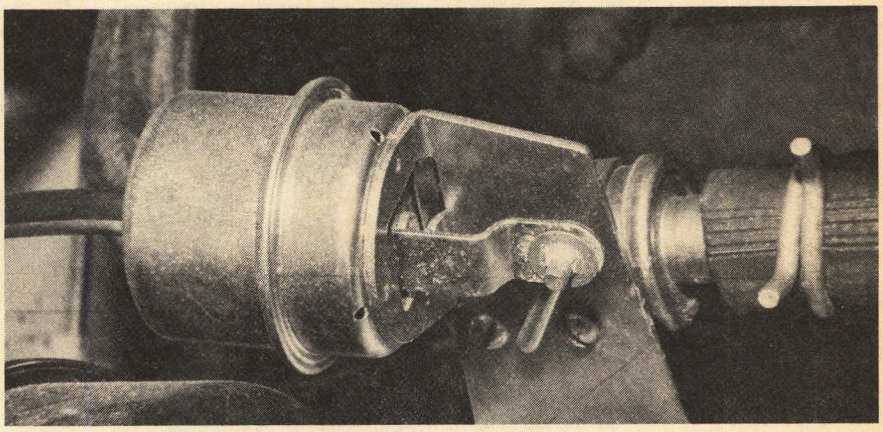
To cure front wheel static, install a collector spring and dust cap in each wheel. For tire static, radio shops have a powder available that must be injected into the tire with a special gun. Another cause of static when the car is in motion but not when standing still is a missing ball tip on the antenna.



2. Heater Core



3. Electric Rear Window Defroster



4. Vacuum-Controlled Water Valve

1. Here's the flow in a typical heater system. Note that heater water flows from the bottom to the top of heater core. If your heater isn't working very well, you may have put the hoses on the wrong way.

2. A heater core is really just a small radiator. Very little ever goes wrong with one; being on the firewall or under the dash, it isn't subjected to the flying stones and careless wrench-handling that your regular radiator is. If you do start getting leaks in one, just take it out and bring it to a radiator shop.

3. Many new cars have an optional rear window defroster that is a set of wires built into the glass. There are no moving parts, and it does the job without any blower noises.

4. Vacuum-operated water valves like this '71 Plymouth unit are relatively trouble-free, as there are no cables to bind or need adjustment.

ANTENNAS

A typical manual antenna may be readily removed for repair or replacement. Power antennas, except for tightening and cleaning, are best left to a specialized shop. Antennas should be kept clean at all times but not waxed. An occasional wipe with an oil moistened cloth is all that is necessary for lubrication of the power type. The quick check for antenna problems is to borrow one that is known to be good, plug it into the radio and hold it out the window of the car with, of course, a wire connection to any convenient ground. If the radio now plays, or plays better, the existing antenna should be repaired or replaced. If the radio gains volume when you touch an installed antenna, it is an indication of a poor ground.

RADIO REMOVAL

The receiver is supported primarily by attachment points at the two control knobs. There may be one or more supporting brackets at the rear of the unit. The attaching sleeve screws are behind the control knobs and of course the power, ground, speaker and antenna wires must be disconnected. On some air-conditioned cars it may be necessary to remove a portion of the duct work to allow clearance for radio removal. Repairs to the receiver should not be attempted by anyone but specially trained personnel.

Accessory Fix-it Tips

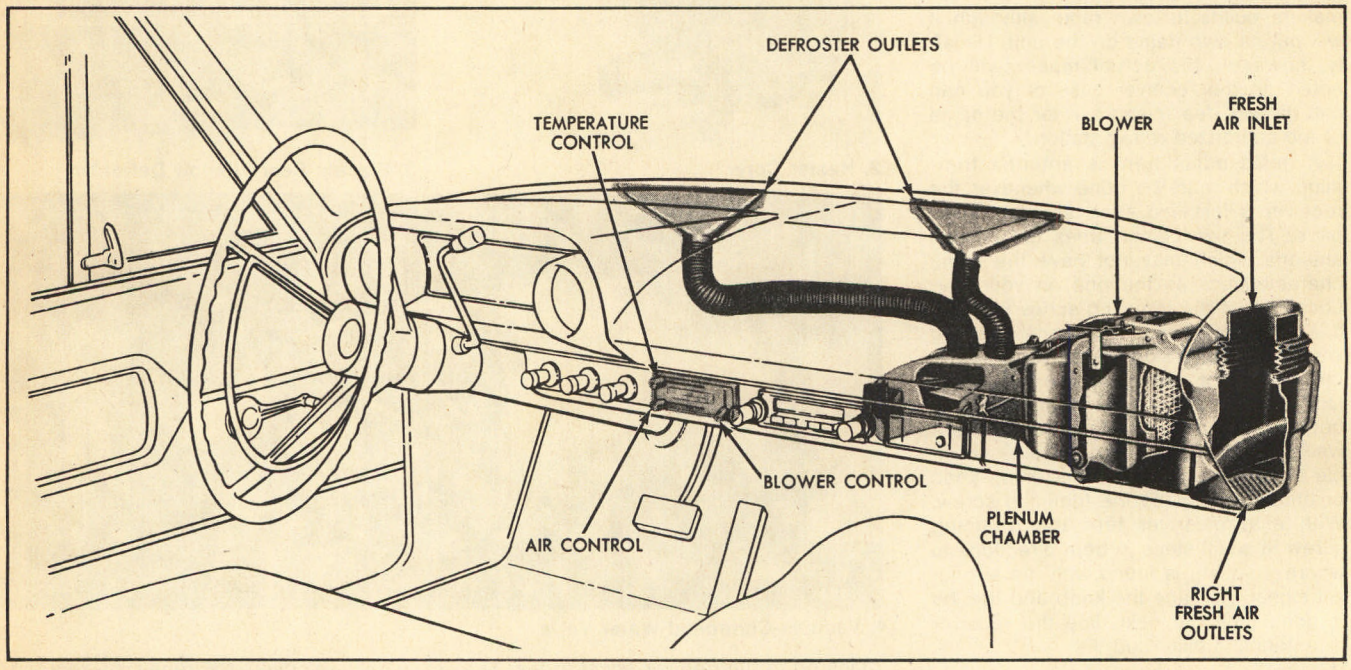
SEATS

Since the invention of the adjustable front seat, manual or power, the cushions of necessity became an integral part of the seat frame, which in turn is attached to the floorpan through the adjusting mechanism.

The adjuster is mounted to the floorpan by only two bolts, but alternate holes are provided in the adjuster for each of the bolts, one on either side of the center hole used by the factory. With the car on a hoist, these bolts may be removed and repositioned as desired to change the base of adjustment without removing the seat from the car. For changing the vertical base of adjustment, shims in these bolts may be removed or added as desired. For fore-and-aft change of permanent adjustment, the satellite track on the other side of the seat should use the same holes. In a change in the vertical, the number of shims on each side should match to prevent an uncomfortable tilt and possible binding of the seat in its slides.

Worn parts in the adjusting mechanism may be replaced by removal of the attaching bolts, which frees the assembly from the seat frame and allows it to be removed for bench maintenance. Each manufacturer's design varies in detail but the parts are straightforward and easy to work with.

Seatback latches are now required on all non-rigid seatbacks by the Federal government. Some use a much more elaborate mechanism that combines this latch with a reclining feature. In this design, the front seatback may be removed without disturbing the cushion or frame. The rear seat cushion is held in place by tabs and may be readily removed. The removal of the rear seatback may, in some cases, require loosening of the attaching points for the package shelf (accessible through the trunk) and possibly



1. Under-Dash Heater Installation

1. On most modern cars the heater is in combination with the defrosting and sometimes the air-conditioning systems. Some types, as here, mount under the dash, others on firewall.

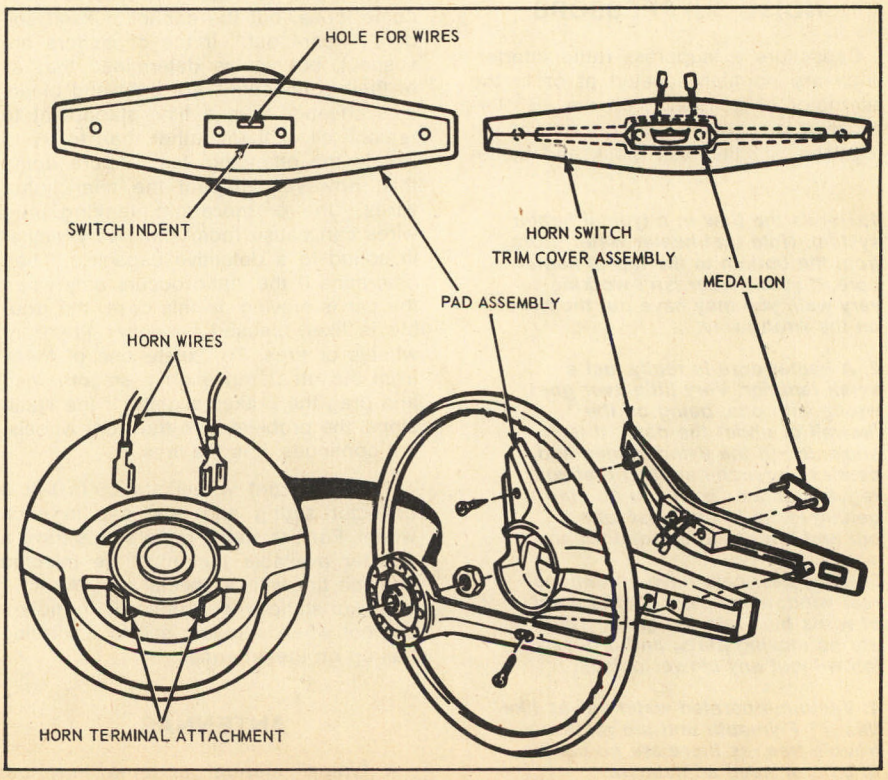
2. Getting at the horn switch on most late cars with 2-spoke wheels means removing trim cover (usually padded).

3. About the only test you can make on a horn is for current draw. Hook up a voltmeter and ammeter as shown. The normal current draw for a dual-horn car is between 4 and 6 amps.

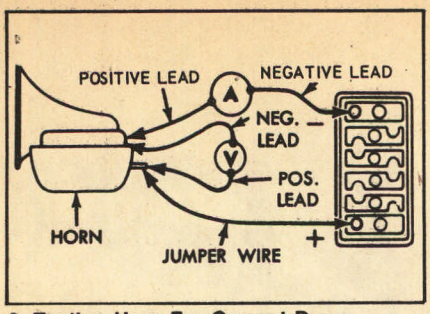
4. On most cars the door panel must be removed to get at the door lock, but on this '63 Ford you merely pry the retaining clip (arrow) out and pull the lock from the outside.

5. Once the lock is outside the door, a screwdriver can be used to pop off the retaining C-clip, and the lock is off and ready to be fixed or changed.

6. Cadillac has a vacuum-controlled trunk lock that shuts automatically when the lid is pushed down. Arrow points to roller that is the control mechanism. Trunk may be opened with key or by button in glove compartment.



2. Two-Spoke Wheel and Horn Switch



3. Testing Horn For Current Draw

rear window moldings. In either case, the procedures involve only the loosening of attaching screws.

The motor of an electric seat should be serviced by a specialized shop. The wiring here is uncomplicated because the switch is adjacent to the motor, but the circuit is routed through the fuse block from the power source.

MANUAL AND POWER WINDOWS

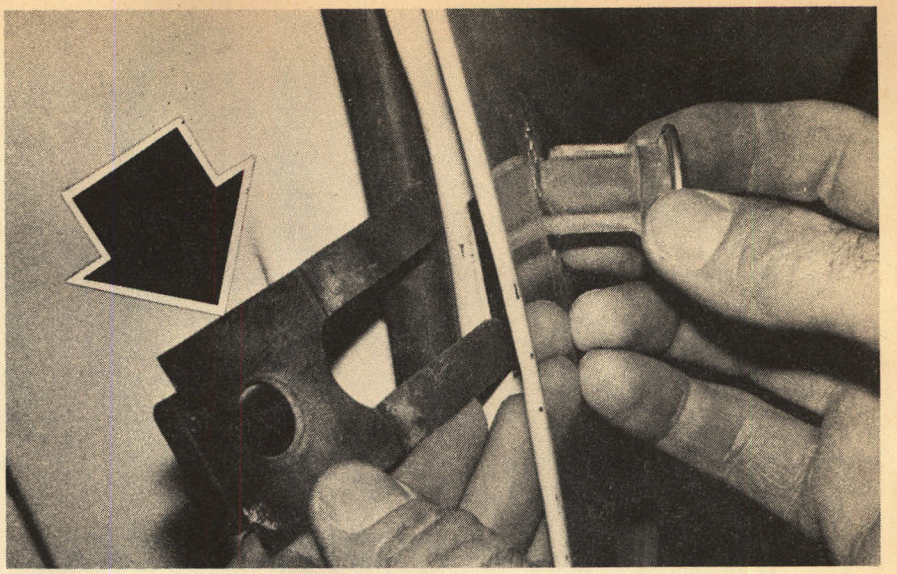
For economic and safety reasons, two types of "shatter-proof" glass are used in an automobile. The side and back windows are usually made from tempered glass which has the characteristic of fragmenting entirely into relatively harmless particles when broken. Sometimes the sheet doesn't disintegrate but visibility through it is reduced to near zero. For this reason another type of glass, called laminated, is used in windshields. As the name implies, this is a sandwich composed of two layers of glass separated by transparent plastic. The plastic isolates breaks, and visibility is maintained if the window is impacted.

Replacement glass for side windows may be of either type. Tempered glass must be cut to shape before the tempering process, so a glass shop will generally stock pre-cut forms for the most popular cars and cut laminated glass on a custom basis to fit rarer makes and body styles. Glass removal and replacement must be preceded by at least partial disassembly of the winding mechanism which, in turn, requires removal of the interior handles and upholstery trim panels.

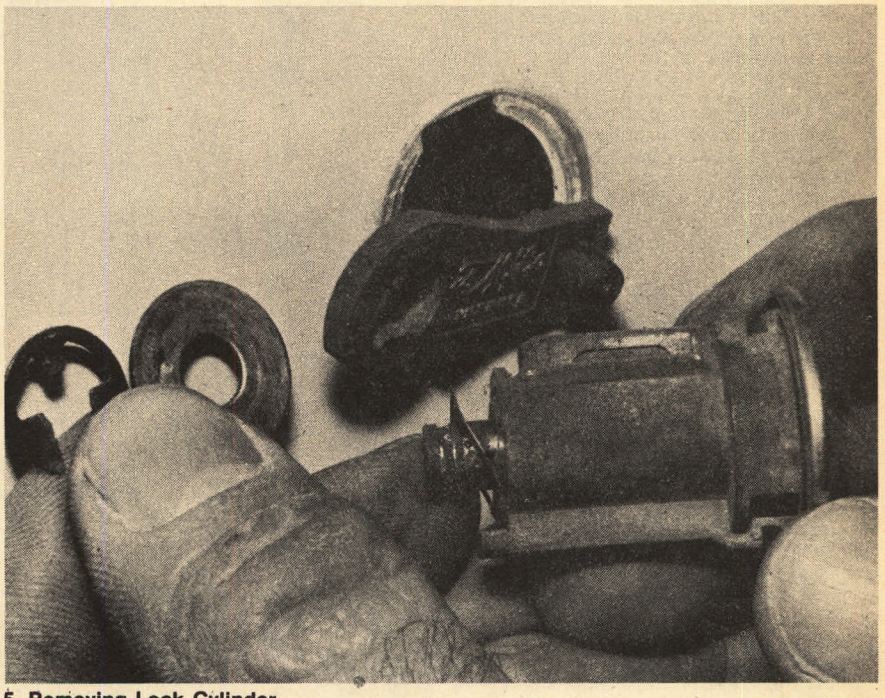
WINDOW ADJUSTMENTS

There are adjustments you can make to compensate for normal wear. A common problem is a loose vent window (of the non-crank type) that won't keep its position against the airstream. A lower pivot nut at the bottom of the window regulates the tension, and you can get at this nut to tighten it by removing the inner window-to-door molding.

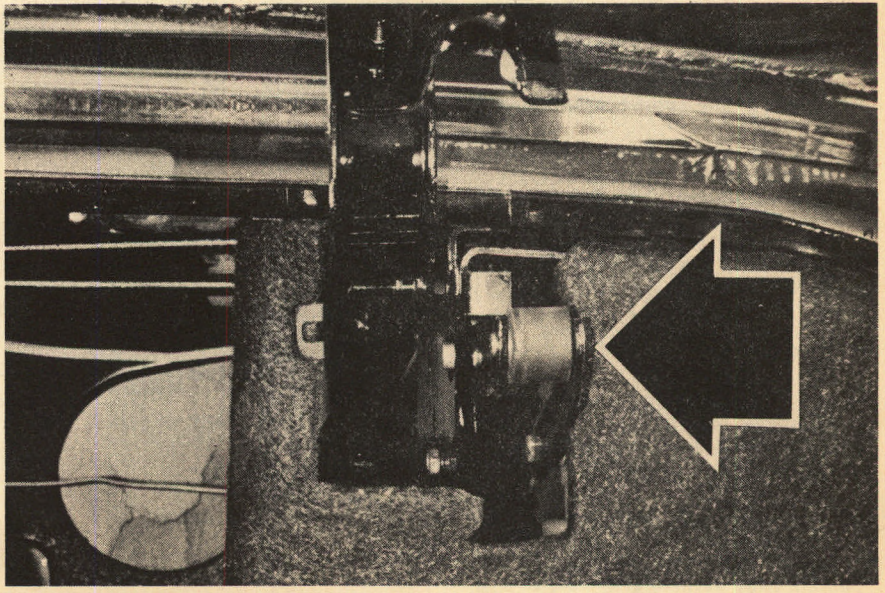
Adjustments to the regulating mechanism of any of the main side windows requires removal of the trim panel. First remove the window-to-door molding and the arm rest. Both of these items are attached with sheetmetal screws, although in the case of the arm rest, the screw heads may be hidden under plastic covers. Next, remove the inner door and window handles. Unfortunately, some of these require special tools. The trim itself is attached to the door struc-



4. Removing Lock Retaining Clip



5. Removing Lock Cylinder



6. Cadillac Trunk Latch

Accessory Fix-it Tips

ture by various types of clips that can be pried out with a screwdriver.

Most window adjustments can compensate for normal wear or correct leaks and wind whistle caused by misaligned glass, and are self-explanatory.

Anytime the trim panel is removed from the door, it is a good idea to lubricate the gears at various rubbing points of the window regulator with a heavy grease that will not run off and stain upholstery in hot weather.

1. If your doors don't fit or latch properly, the door may be just out of alignment. It can be realigned by loosening the screws on this striker plate for readjustment.

2. Some elements can be changed by unscrewing them from the knob, but you must push the sleeve back and grab the end of the element itself in order to unscrew it.

3. With the element unscrewed, the whole thing comes apart easily. The replacement element must be the same size and shape or it won't fit into the dash receptacle. Elements seldom go bad. Look for a blown fuse first, either at fuse block or lighter.

4. Cartridge fuse screws onto the rear of many lighters. Check for continuity with a test light. If it's blown, you have to replace it.

5. Removing lighter shell shows prongs that grab end of the element. Both the internal (top) and external types are used. They're not interchangeable.

6. Collar on this Ford lighter picks up light from behind the instrument panel to illuminate "lighter" sign. Element is covered by ash guard.

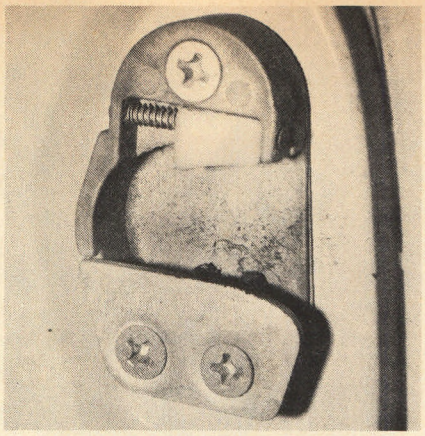
7. Here are several of the methods the factories use to eliminate static in radios. Suppression capacitors can be installed on the coil, generator and other electrical components; GM cars use a metal shield over the ignition points; spring-loaded dust caps can be used on the wheels; and most cars in recent years have used metal ground clips between the hood and the cowl.

8. Seats are hard to work on because the cushions cover up the works. If you remove the cushion, your chances of fixing the seat are better.

9. It's a sign of the times, but you see quite a few of these antennas made from coat hangers because someone vandalized the antenna. They work, but not too well.

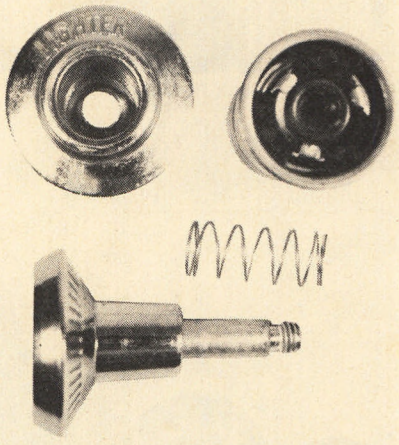
10. Don't forget switch as a source of trouble on electric seats. If the seat works only when you wiggle the switch, you may have bad contacts.

11. At left is the mechanism for a GM 4-way power seat. For comparison, the model at right is a 6-way, which has the extra vertical gear nuts that raise and lower the seat.

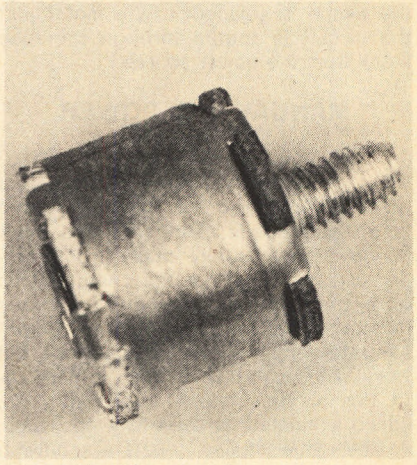


1. Door Lock Striker Plate

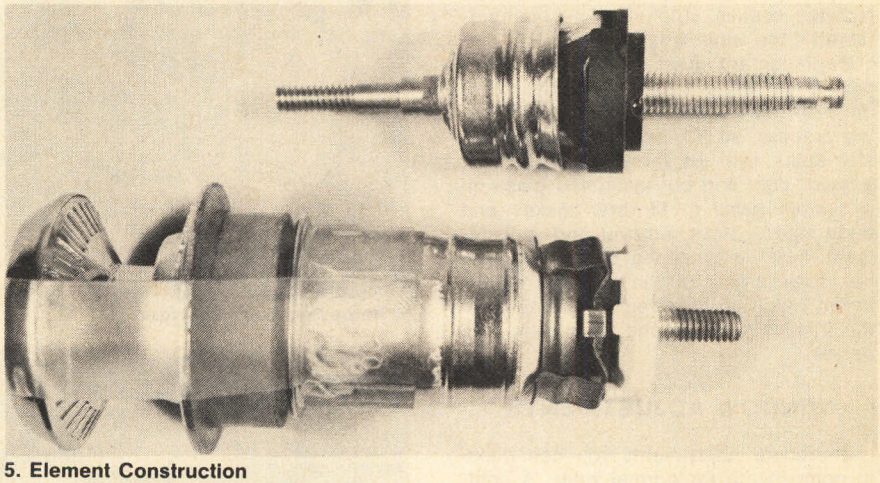
2. Removing Element



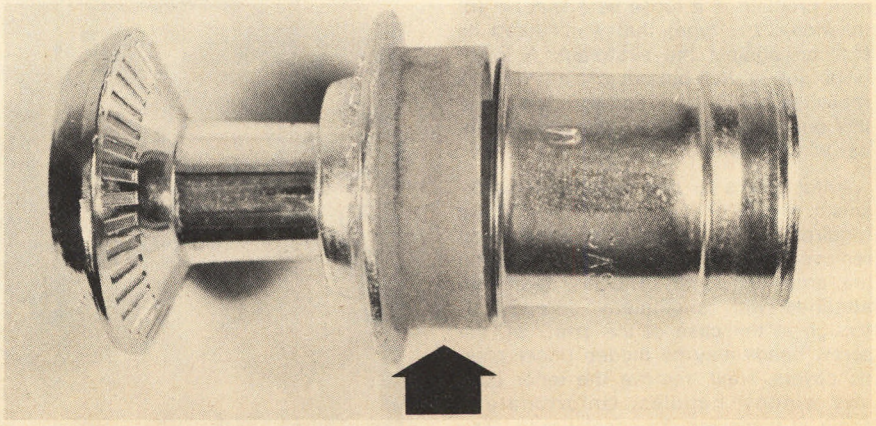
3. Disassembled Lighter



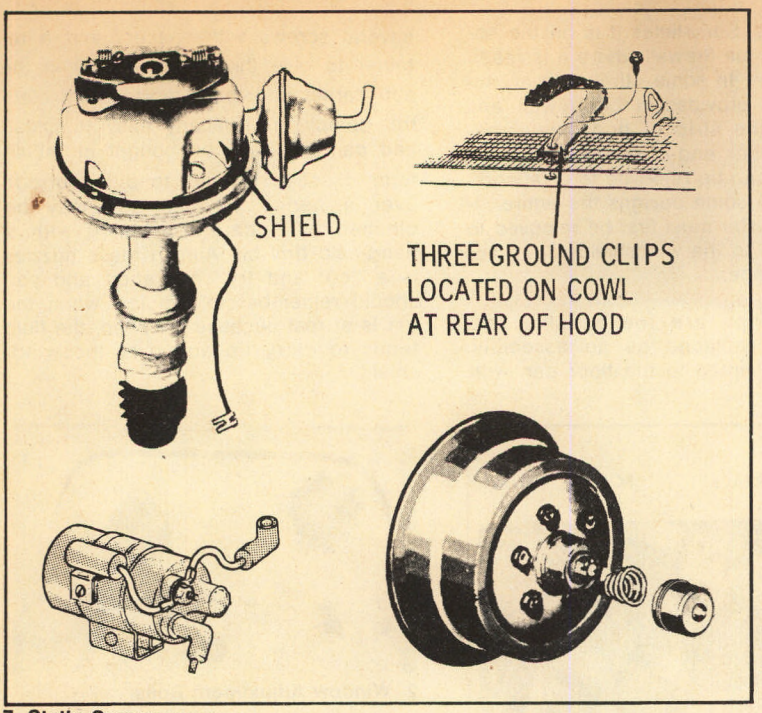
4. Cartridge Fuse



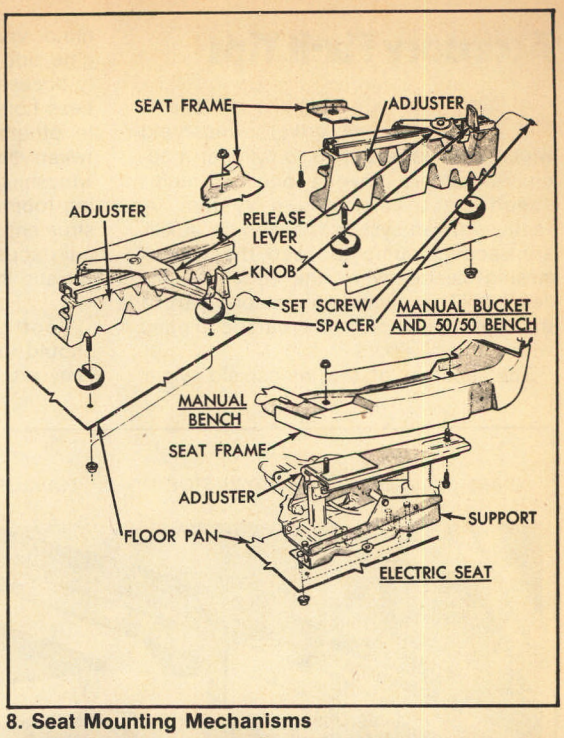
5. Element Construction



6. Illuminating Collar



7. Static Suppressors



8. Seat Mounting Mechanisms

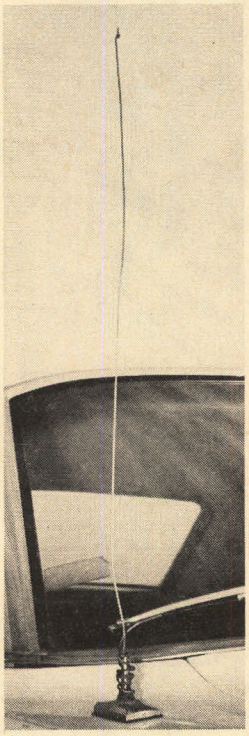
ELECTRIC WINDOWS

Replacement or lubrication of the separate, permanent magnet-type motors that operate each window requires removal of the regulating mechanism. We have advised against the owner-mechanic attempting this for reasons described above. If you do go ahead, the regulator assembly must be held in a vise when the motor is removed from it to prevent the assist spring from unwinding. If the master switch is malfunctioning, it must be replaced as a unit. The window circuit utilizes a circuit breaker with the current source being the ammeter.

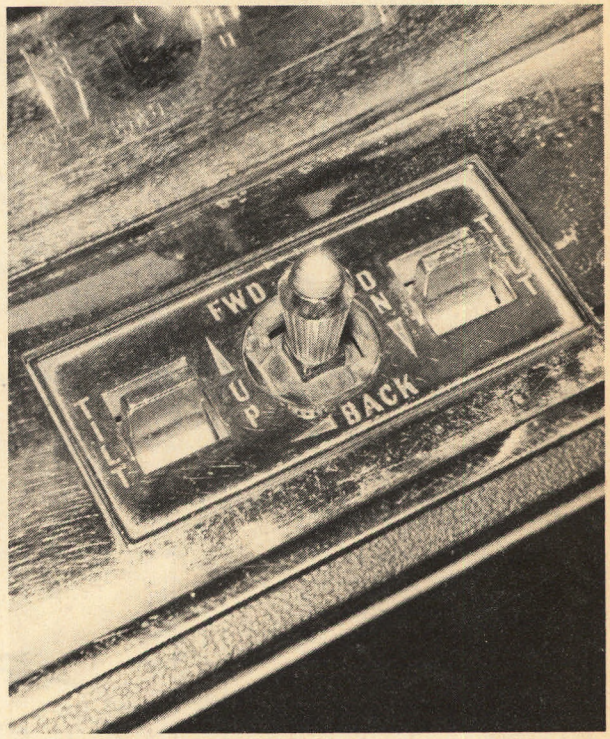
WINDSHIELD WASHERS AND WIPERS

Windshield washers fall into three general categories. The simplest type is a foot-operated pump mounted on the floorboard or cowl on the left side above the headlamp dimmer. It is connected by hoses to the fluid reservoir in the engine compartment and to the nozzles. The simplest electric type is at the bottom or adjacent to the fluid reservoir and is actuated by a switch incorporated in or adjacent to the wiper control. A "deluxe" type of pump is part of the windshield wiper motor and when actuated, also operates the wipers for a predetermined number of strokes.

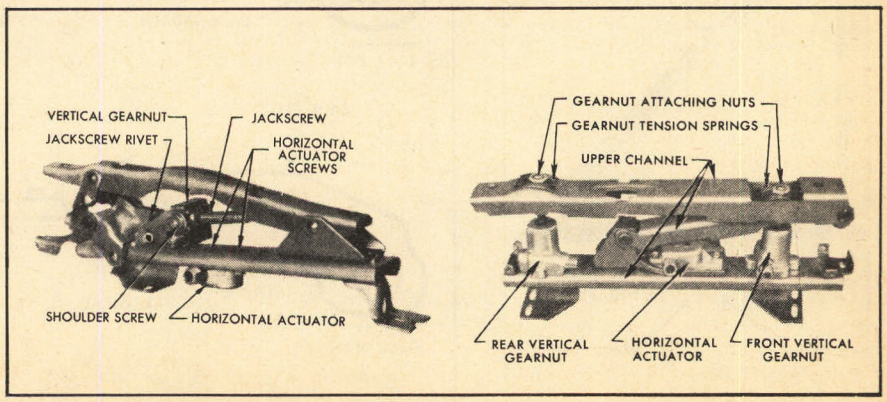
Chemicals are sold in all service stations for mixing with water in the system. In winter the chemical acts as an antifreeze, with the degree of protection determined by the graduations on the bottle. The antifreeze not only keeps the solution from freezing in the bottle and breaking it, but prevents the solution from freezing solid when it hits the ice cold windshield. A partially frozen solution can create enough load to burn out the pump motor. In the summer, a solution of chemicals and water improves cleaning action to cut those bugs off the glass.



9. Homemade Antenna



10. Dash Control for Six-Way Seat



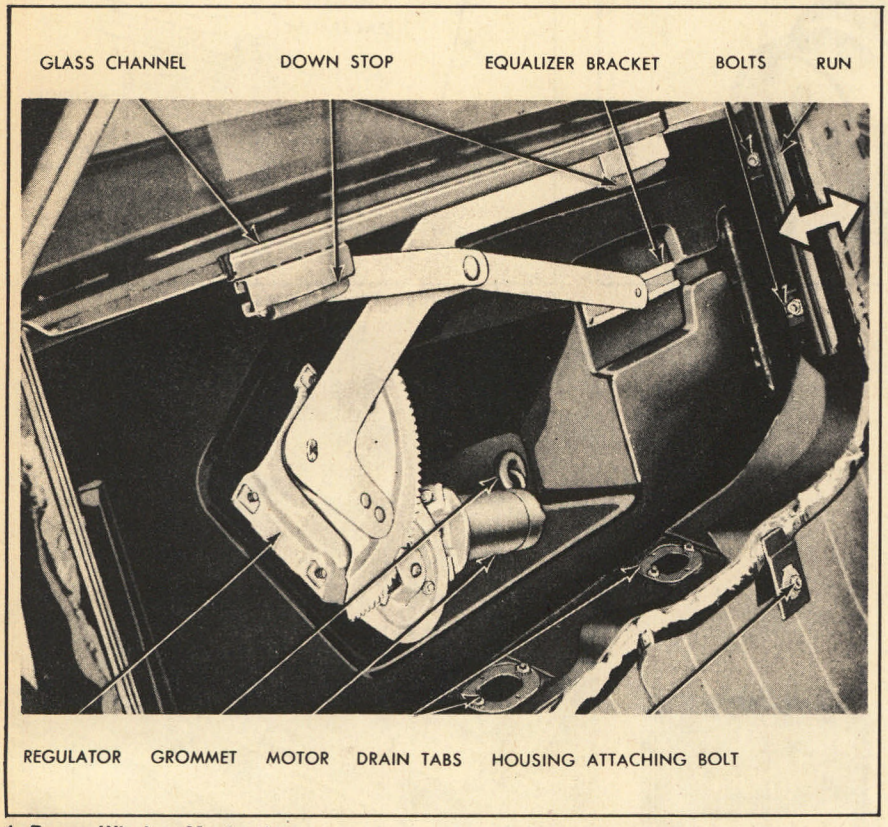
11. Four-Way and Six-Way Adjusters

Accessory Fix-it Tips

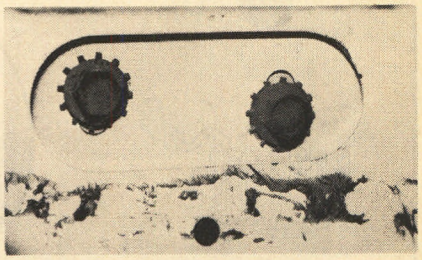
In late-model cars, Rambler is alone in still using a vacuum-driven windshield wiper and this is only for 6-cylinder models. All others have a one- or multi-speed electrically driven system. A vacuum-driven system requires an auxiliary vacuum pump to keep the wipers moving steadily when the engine is under load. This pump is an integral part of the fuel pump on most cars equipped with vacuum wipers.

The location of the windshield wiper motor varies. Sometimes it is on the engine side of the firewall where it is readily accessible. In some other cars an access hole is provided in the firewall, and in others, the strip of body metal between the back end of the hood and the windshield can be removed to give working room. In some designs the entire instrument cluster must first be removed to gain access to the windshield wiper motor and linkage.

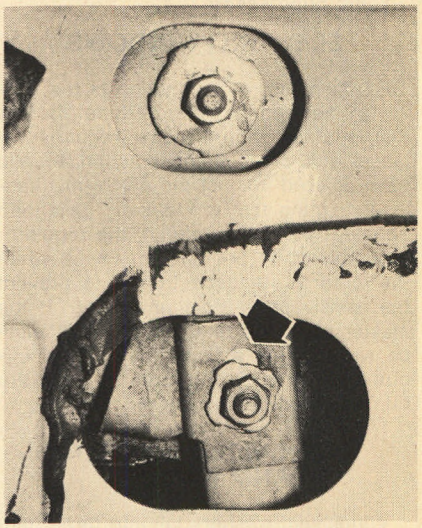
Foot pumps are inexpensive and should be replaced as an assembly. They are mounted to the floor pan with several screws with spacers and a retainer to give the mount rigidity in the soft carpet and mat. Replacement electric pumps are similarly easy to install and can generally be bought in rebuilt form. Ejection nozzles tend to corrode over a period of time and may be cleaned by a careful reaming with a hand-held drill bit. Aiming these nozzles is a "cut and try" operation and you should remember to aim low when the car is at rest because at speed, the fluid tends to carry up and over the windshield.



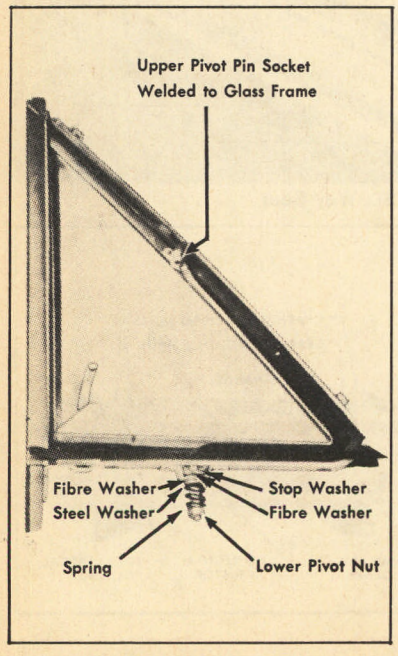
1. Power Window Mechanism



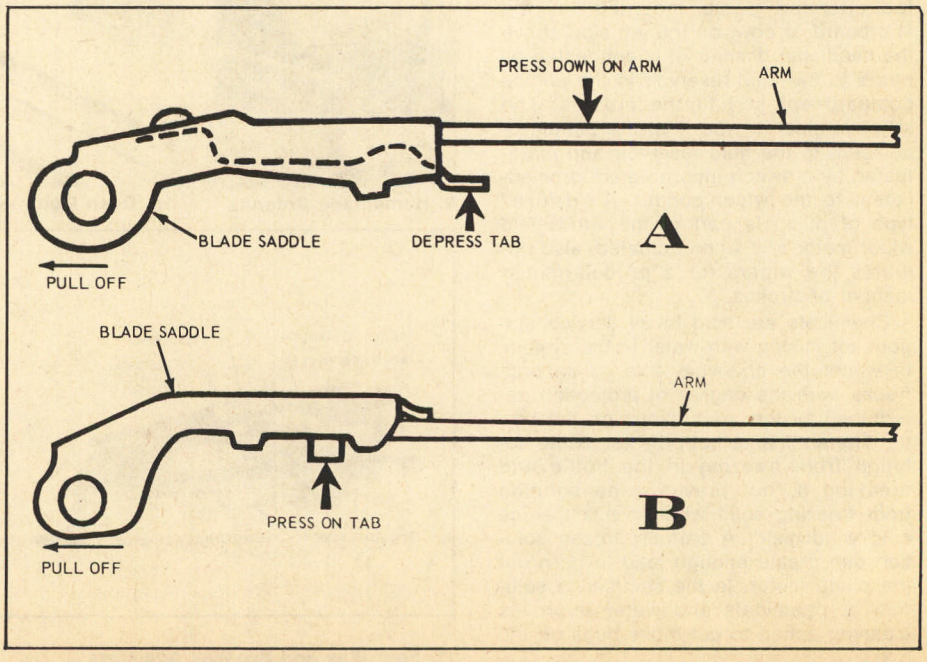
2. Window Adjustment Bolts



3. Window Channel Adjustment Points



4. Vent Window Assembly



5. Bayonet-Type Wiper Blades

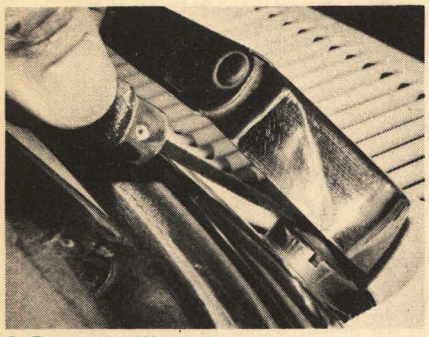
WIPER MOTOR AND LINKAGE MAINTENANCE

Most wear in the linkage can fortunately be compensated for by adjusting the position of the wiper arms. Most are attached to their shafts by a conventional cap bolt. If no bolt is evident, a special tool, varying by the make of the car, is required to remove the wiper arm without damaging it.

Replacement wiper blades are obtainable in any service station. In newer designs only the rubber is replaced; older cars require a complete blade assembly. Extreme care should be taken not to bend the wiper arm when replacing a blade because it takes only a slight misalignment to cause metal to contact glass and the result is a permanently marred windshield.

The decision as to whether you should attempt to work on the linkage and motor or buy this service depends entirely upon its accessibility. Once you get at it, there is nothing very complicated about the assembly, and wear points are quite evident by their sloppiness. Unlike most other assemblies on the car, wiper linkage parts are sold separately. When you find the worn part, bring it with you to the dealer's parts counter so you can be sure you get the right replacement.

The easiest way to fix an electric wiper motor is by replacing it. New motors are rather expensive, but you can get good bargains on used ones in wrecking yards if you are willing to remove it from a wrecked car yourself. Vacuum wiper motors can usually be made to work, even though they haven't operated for years; simply squirt a little oil into the motor and work the shaft back and forth so that the oil lubricates the mechanism. A vacuum wiper rejuvenated by this method will certainly not have the power and speed of a completely overhauled or new unit, but at least it will work.



6. Removing Wiper Arm

7. Wiper Shaft Spline

8. Windshield Washer Assembly

1. Take care in repairing a motor for a power window, as the spring in the regulator is extra powerful. Motor and regulator should be removed as a unit. The regulator should be clamped in a vise, so the gears can't move, before you loosen the motor.

2. If adjustment is not obvious, mark the position of the bolts as they are, then loosen them for adjustments.

3. Slotted hole behind clamp bolt is to allow adjustment of window channel. To get to these adjustments, you have to remove the interior trim panel.

4. Loose, floppy, hand-operated wind wings (vent windows) are usually a result of loose springs on post.

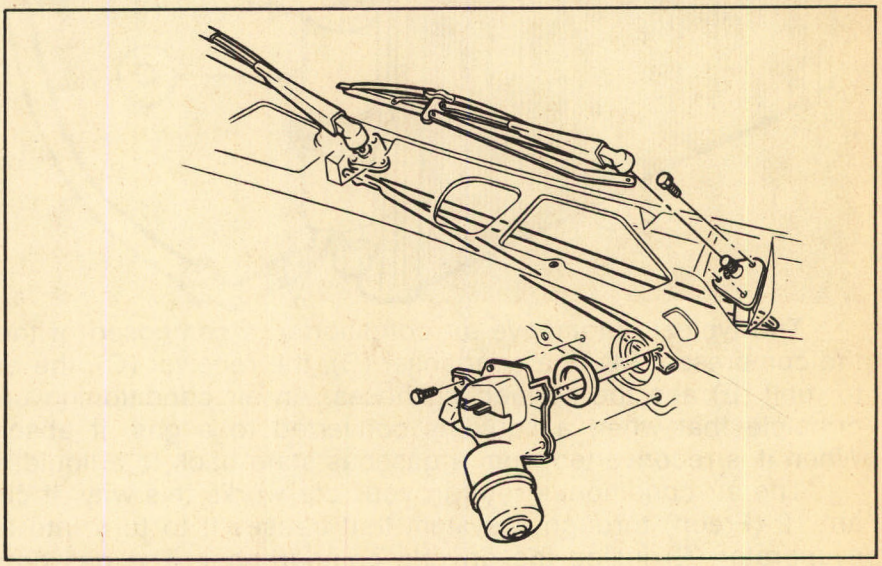
5. Two of the most common wiper blade types are the Trico (A) and the Anco (B). Both of those shown are bayonet type; there are pin-types also.

6,7. A little tab under the wiper arm must be lifted to remove the arm. You can slip it off with a screwdriver. Arms will go back on the splined part in any position. If the blades don't stop in the right position or hit the window frame, you can reposition arm.

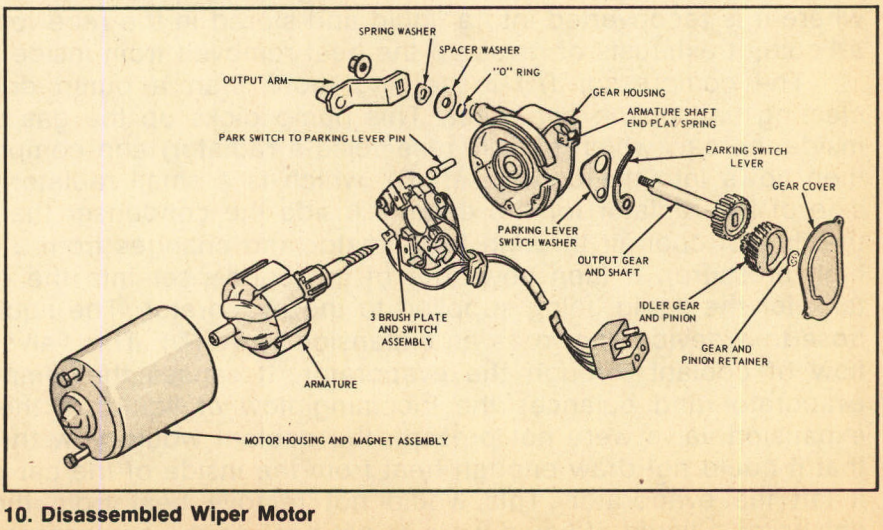
8. A windshield washer consists of a reservoir for the water/detergent mix, usually a plastic bag or box, and a small motor which pumps the fluid up through the hoses onto the windshield.

9. Most wiper motors attach to the firewall, with the linkage to the wiper arms being under the dashboard.

10. This is a late Ford wiper motor, which has the park switch adjustment inside the wiper. You should have a shop manual to go by if you're going to disassemble an electric wiper.



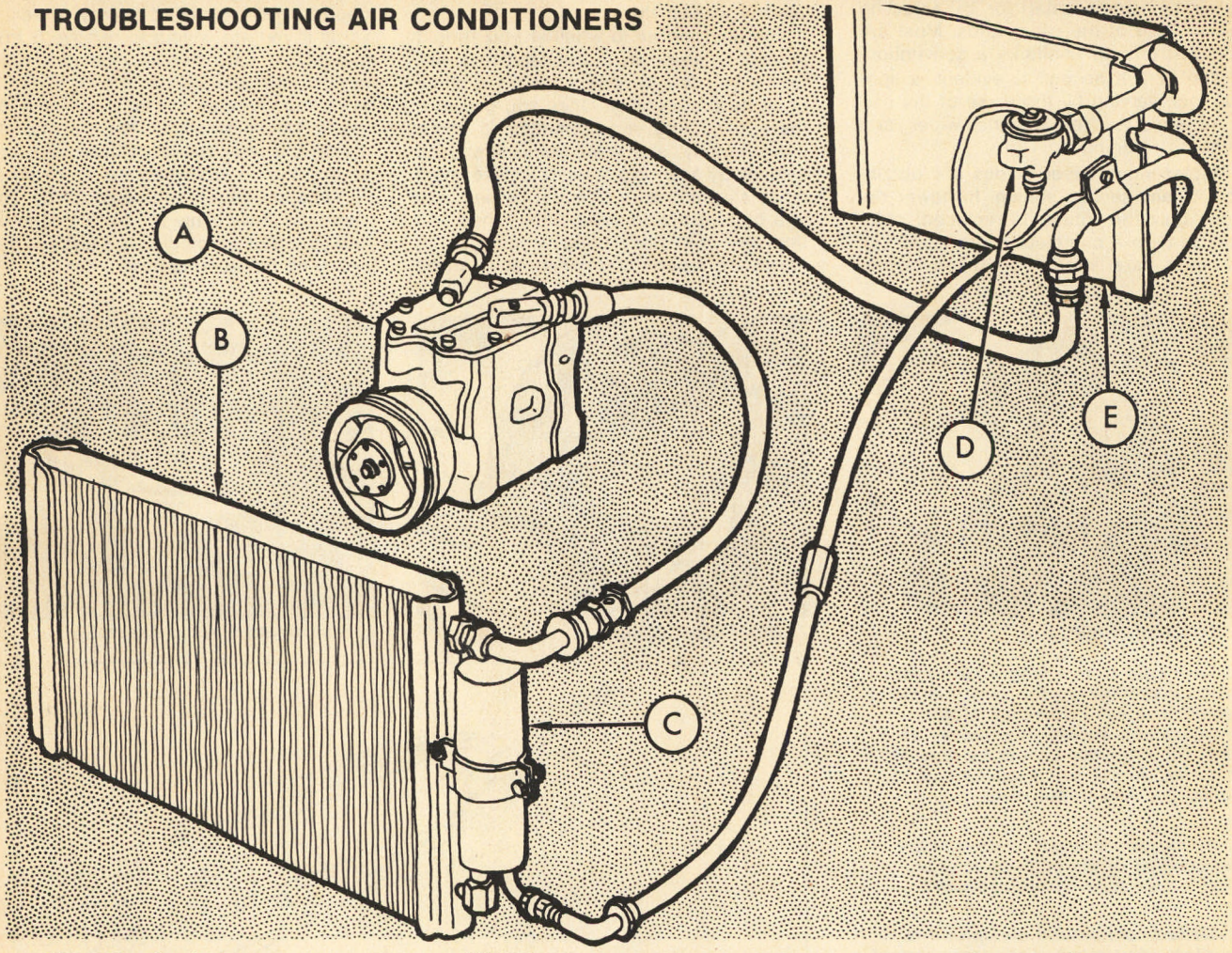
9. Wiper Motor and Linkage



10. Disassembled Wiper Motor

TROUBLESHOOTING AIR CONDITIONERS/HEATERS

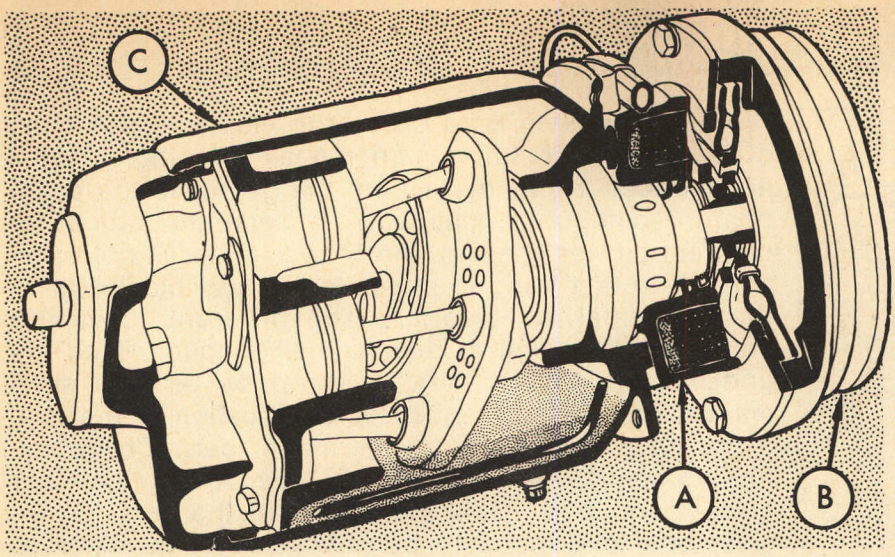
TROUBLESHOOTING AIR CONDITIONERS



The typical automotive air conditioner is composed of the following pieces of equipment: the compressor (A), the condenser (B), the receiver (C), the expansion valve (D), the evaporator unit (E) and the connecting hoses. An air conditioning unit works on the simple physical principle that when a liquid is converted to a gas, it absorbs heat from its surroundings. When it is reconverted from a gaseous state back to a liquid, it gives up this heat.

The air conditioning unit in your car works this way. It circulates a liquid called Refrigerant 12 (Freon) through a system that causes it to turn into a gas while passing through the evaporator (E) inside the driver's compartment. The gas draws heat from the air inside the car, then is pumped back into the engine compartment through lines to a condenser (B), where it is reconverted into a liquid and stored in the receiver (C). As the gas turns back into a liquid, it exhausts or gives up the heat removed from inside the car.

The compressor (A) is nothing more than a pump driven by a belt, like the power steering unit or the generator. This pump picks up the gas coming from the evaporator (E) inside the car (which closely resembles a radiator) and compresses it. The high-pressure gas then flows into the condenser (B), which is a small radiator usually fitted in front or to the side of the radiator for the engine. Inside the condenser the high-pressure gas is cooled by the flow of cool air through the radiator and changes from a gas back to a liquid (still under high pressure). It then flows out of the condenser into the receiver (C), which is a holding tank for the liquid being supplied to the evaporator. The liquid coolant then flows through a hose to a device known as an expansion valve (D). This valve is the controlling factor for the flow of coolant through the evaporator. It senses the temperature of the gas leaving the evaporator and balances the incoming flow of liquid so the system works properly. If the expansion valve were not present, the coolant would flow through the evaporator so quickly that it could not draw enough heat from the inside of the car and would still be a liquid when it left the evaporator. This would not remove heat from the car. The compressor cannot compress a liquid. If liquid were to get back to the compressor, it would be damaged.



The compressor is connected to the drive pulley on most cars by a magnetic clutch (A). This device disconnects the compressor from the drive pulley and belt if the temperature drops below the temperature selected by the driver. This stops the compressor from working even though the belt is still turning the pulley. When the temperature inside the car again rises enough to require cooling, the clutch automatically engages and starts the compressor working.

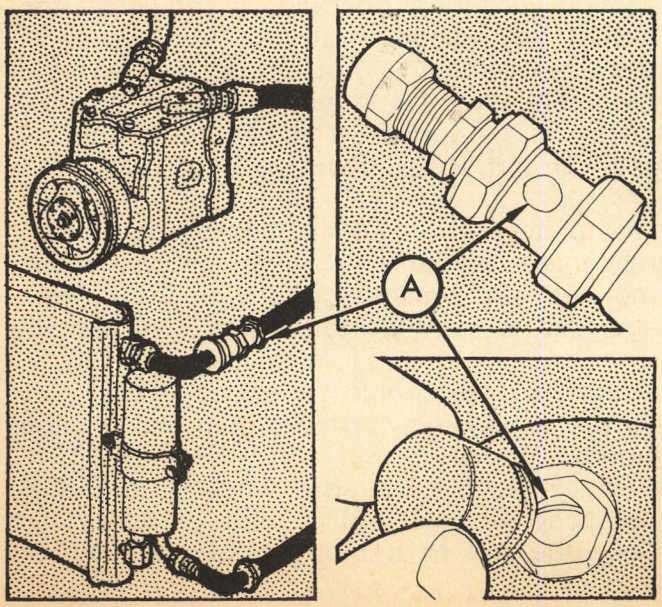
Inside the driver's compartment are the evaporator and the controls for the air conditioning. There is an electric motor and fan incorporated with the evaporator to direct air over the evaporator and out through adjustable vents to cool the inside of the car.

WARNING: THE REFRIGERANT USED IN AIR CONDITIONING SYSTEMS IS HAZARDOUS. IT IS AN ODORLESS, TASTELESS GAS OR LIQUID AND CANNOT BE READILY DETECTED. DO NOT ATTEMPT TO DISASSEMBLE ANY PORTION OF THE SYSTEM. TAKE THE CAR TO A QUALIFIED AIR CONDITIONING MECHANIC. THE REFRIGERANT BOILS AT 21 DEGREES FARENHEIT AND CAN SEVERELY INJURE SKIN BY FREEZING.

SYSTEM DOES NOT COOL

Check the drive belt for signs of glazing or fraying. Examine it to see if it is tight enough to prevent slipping when the air conditioning is turned on. If the belt shows signs of wear, replace it. Using two people, check out the operation of the clutch (A) between the pulley (B) and the compressor (C). Have one person sit in the car and start the engine. Have him turn the air conditioning on and off several times while you watch the clutch. You should be able to see the clutch operate and hear a sound each time the clutch engages. If the clutch does not operate, the trouble could be in either the clutch or the sensing device which operates it.

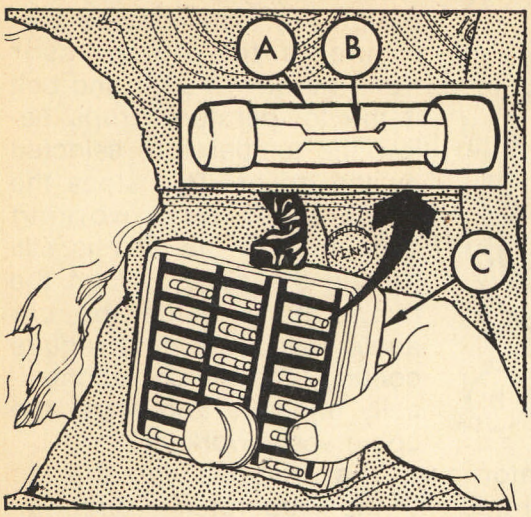
Visually check all of the hoses and connections for obvious signs of worn or ruptured areas. Look at the condenser to see if it is clogged with dirt, leaves or bugs. Materials that clog up the fins of the condenser can result in a loss of cooling efficiency. If there are any obvious spots of ice or frost on the outside of the condenser after the air conditioning has been operating for a while, it can mean that there is some internal destruction in the condenser core.



If the compressor and condenser appear to be working, examine the sight glass (A). This gives you a look at the condition of the coolant itself. There may be bubbles in the sight glass for a few moments just after the system is turned on, but they should soon disappear. If the liquid is cloudy or foamy, there is something wrong, probably moisture contamination. If the bubbles persist more than a few moments you are probably low on Freon coolant. Take the car to your local air conditioning mechanic for further checking.

The presence of the bubbles in the sight glass may indicate that the filter element in the receiver unit is used up. Most receiver units have a combination filter/dehydrator to remove moisture and small dirt particles. The receiver can be replaced as a unit, but it is not recommended that the reader do it.

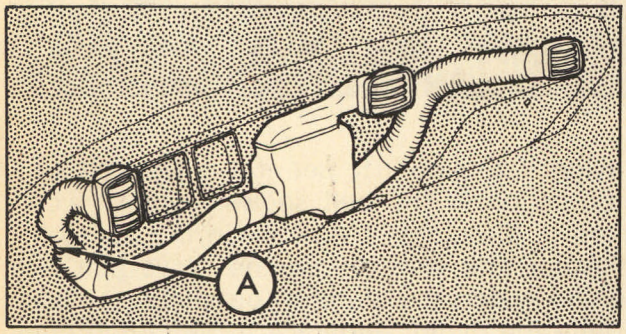
TROUBLESHOOTING AIR CONDITIONERS/HEATERS

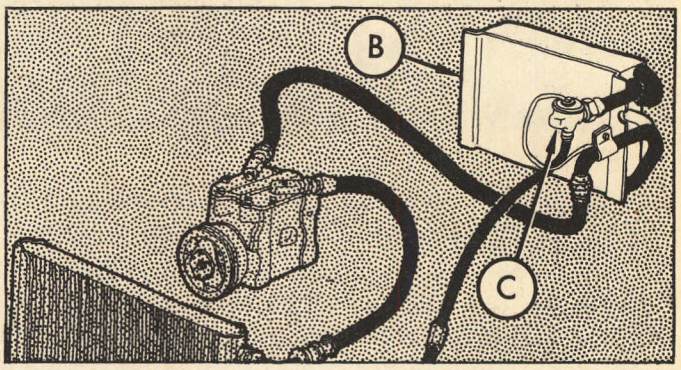


The next step is to check the electrical operation of the system. If turning on the air conditioner does not produce a flow of air from the outlets in the dashboard (some units may have a separate switch for different blower speeds), the blower motor is not operating. The first thing to check is the fuse block (C) for the electrical accessories. The different fuses are marked with writing to denote their function. Find the one marked A/C or AIR. (If in doubt, see the shop manual or owner's manual for the location of the fuse block and markings for your model car.) Check the fuse to see if it has blown. The fuse (A) may be clear glass, permitting visual inspection of the wire (B) inside, or it may need to be checked with a meter as you would check continuity of a wire. (See the chapter on electrical accessories.)

If the fuse checks out as good, examine the wiring and the switch. You may wish to check the switch with a meter as you did when checking out the starter and ignition systems. If both switch and fuse are good, the problem is most likely in the blower motor itself.

SYSTEM COOLS PARTIALLY





If the air conditioner works but will not deliver sufficient cooling air, the problem may be a slipping clutch mechanism or a loss of coolant from the system. It is also possible that something other than the air conditioner is at fault. Check the fresh air vents to see if one is stuck partially open, allowing hot outside air to enter the car. Also look at the ducting for the air conditioner which runs from the evaporator housing to the outlets. One of these may be collapsed or loose (A). If so, replace the ducting. A torn or detached duct can be repaired with tape.

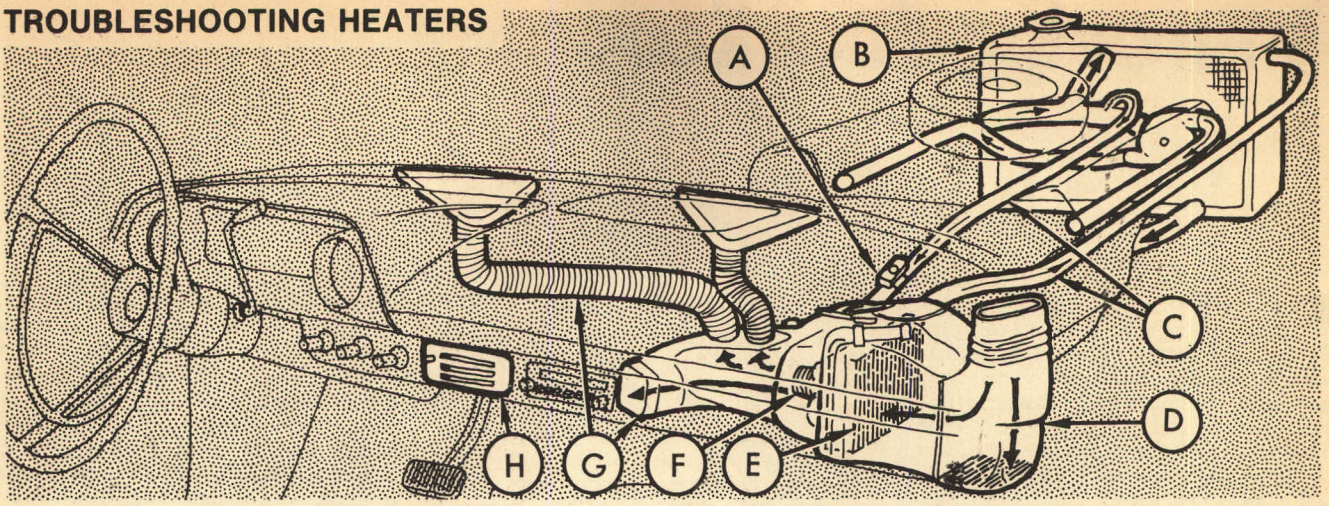
The evaporator unit (B) itself can be the problem. In normal operation it should be cold and "sweating" (condensed moisture on the outside), but it should not have any frost or ice on it. If there is frost or ice on the surface of the evaporator, the problem is most likely the expansion valve (C) or the temperature sensor element. The evaporator is equipped with a drainage system to remove the water that condenses on the surface. This should be checked to make sure it is working properly. If it is clogged with dirt, it can cause water to drip on the floor carpet.

Air conditioners that work but do not cool completely are usually suffering from coolant loss. This can be repaired by having an air conditioning mechanic recharge the system with a fresh load of coolant. Some coolant loss is normal, but if efficiency falls off within three months or so after being recharged, the leakage rate is too high for normal use and the system should be checked.

For best results and long operating life, air conditioners should be operated every few days even in cold weather. It is not necessary to run the system for more than two or three minutes, but it should be done at least twice a month.

We do not recommend that you attempt to troubleshoot the internal workings of the air conditioner or recharge the system. It requires special tools and knowledge which are beyond the scope of basic troubleshooting. Take the car to a qualified air conditioning mechanic for detailed troubleshooting and repair.

TROUBLESHOOTING HEATERS



The heater is nothing more than a small radiator (E) through which circulates the engine coolant. It is connected to the engine by hoses (C). A small amount of the heated coolant leaving the engine passes through the heater before going to the engine radiator (B) for cooling. Once the engine is up to normal operating temperature, the coolant is hot enough to warm the air directed over the heater core (E).

The heater is equipped with an electric motor and fan (F), usually with several speeds and a system of ducting (G) to direct the heated air either under the dash toward the floorboards or to the inside of the windshield for defrosting. These ducts have doors in them operated by cable controls (H) mounted on the dash.

NOTE: SOME LARGE AND MORE EXPENSIVE AUTOMOBILES USE VACUUM TO CONTROL DUCT DOORS RATHER THAN CABLES. CHECK THE MANUAL FOR YOUR CAR.

The driver can manually adjust the position of these doors to direct the air flow from the heater as he desires it.

Heat level is controlled in two different ways. One type of heater allows the heated coolant to flow through it at all times. It simply blocks the heat off when not required—by closing doors which prevent air from passing around the core (E). The other type of heater has a valve (A) in the incoming line from the engine to shut off the flow of heated coolant when it is not wanted.

There is very little that can go wrong with a heater. If the fan motor will turn on and run at its full range of speeds, the electrical portion is good.

Basic heater problems fall into three categories: not enough heat, heat all the time or no heat. If there is no heat, it is possible that the coolant is not reaching the heater core (E). This means a collapsed or plugged hose or a frozen valve (A). (In heaters where the coolant flows through the core all the time, the problem will be that one of the doors is not operating correctly to allow air to flow over the core.) If there is heat all the time, the control valve or door is stuck wide open. Not enough heat can mean the valve or door is stuck in a partially open position or the coolant coming from the engine is not hot enough. If the coolant is not hot enough, it could mean the thermostat in the cooling system is stuck open, allowing coolant to pass through the engine so rapidly that it does not get hot quickly enough. If your car is equipped with a temperature gauge instead of a warning light, watch to see if engine temperature rises to normal operating ranges after it has been driven for a reasonable distance.

To reach the heater and the control cables, you will have to get under the dashboard. This can mean the simple removal of some cardboard covers or, in the case of air-conditioned cars, it can mean a day-long task. Check to see that all controls operate smoothly and that doors to ducts open easily and close completely. Usually it is easy to spot a binding door or valve, because the control on the dashboard becomes hard to move or turn.

One other item worth checking out if you have a problem of not enough heat is the fresh air ducting system (D). It can cause problems if one of the doors is sticking partly open, allowing cold air to enter the car. Once in a while, a heater core will spring a leak just like the radiator. It is usually not practical to repair the core, but a good core obtained from a wrecking yard is easy to install on most cars.

Improving Fuel Economy

If you're not yet too sick of the nostalgia fads to think back a few years, remember when no one cared about gas mileage? It wasn't really that long ago that you could buy a gallon of the now-precious motor-nectar for 32¢—even less if there was a local price war amongst the stations. Of all the wars we've ever been in, one that most people would like to see revived is the old-fashioned "gas war," a healthy symptom of a functioning capitalist system but probably gone forever like nickel beer. While you're remembering the good old days, ask yourself whatever happened to that '57 Chevy with 283 engine, 2-bbl. carb and 3-speed standard trans that went 100,000 miles and still got 17 mpg—or better with overdrive. Then jolt yourself back to the present where a new, full-size car is lucky to get 12 mpg after only 10,000 miles.

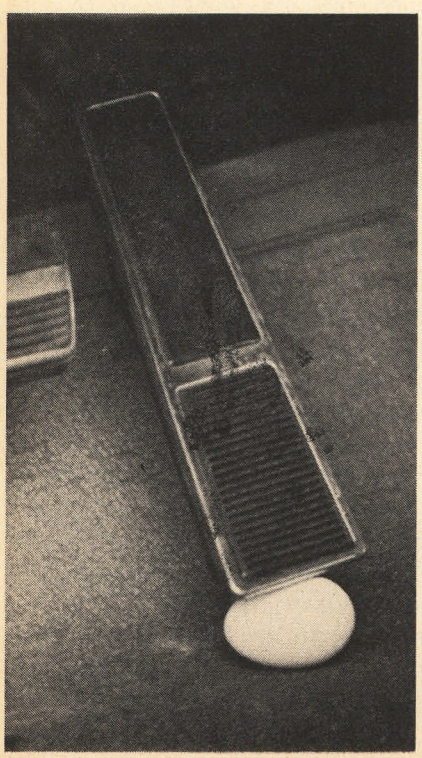
Everyone today is gas-conscious, and well they should be with the cost of the deadly fuel what it is. Anything that focuses the attention of the public like the "energy crisis" is bound to bring out the hucksters who'll sell you the trick mileage device just like they've been selling those phony "spark intensifiers" for the last 30 years. The plain truth is that fantastic gas mileage is very difficult to come by, although respectable gains can be made simply by applying common sense in driving and maintenance.

DRIVING STYLE

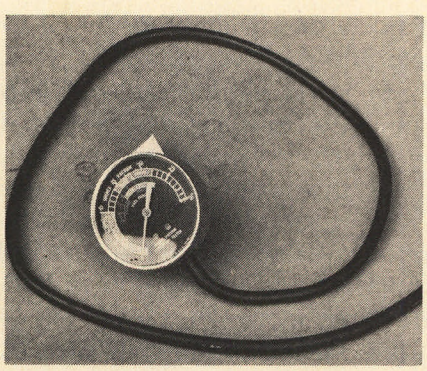
You've probably already read several articles about how to drive with a soft-boiled egg on the gas pedal, but it is true that the difference between a good driver and a poor one is probably 50% in overall gas mileage. Fast takeoffs, high speeds, rapid decelerations and sharp turns all take their toll not only in gasoline but also in *tires*. In one *Motor Trend* test of a new Vega, hard driving netted 19 mpg while very careful driving brightened the picture to an incredible 33 mpg! That's dramatic proof of the difference driving style makes. Whatever your personal opinion of the recent 55-mph speed limits, it is true that driving a constant 50 mph will save over 10% in mileage over driving a steady 65-70 mph. The most important change you can make in your driving is the simplest, just keep an eye on your gas gauge and think about 60¢ a gallon every time you leave a stoplight!

There are other tips that can save you fuel in your driving habits. A very simple one is to always get your gas fillups early in the morning. The gasoline is cold from sitting all night and it's denser than it is later in the day when the storage tanks have warmed up. Being denser, it means that you'll get more gasoline for the same money. For the same reason, the expansion of gasoline, you shouldn't let your tank get below half-full, because the more air that is in your tank around the gasoline, the more the gas in the tank can vaporize. Also, a full tank left parked in the hot sun can overflow and waste precious fuel. So don't leave your car parked in the hot sun when the tank is full (it's not good for the paint job anyway). You've probably all seen a car in traffic which accelerates away from a stoplight with gasoline gushing out of the filler neck, even when the cap is in place. This is a horrible waste of resources and usually is due to a poor original design in Detroit. Cars whose filler cap is behind the license plate rather than up on the quarter-panel have *very* short filler pipes going into the tank, allowing gas to easily slosh out when accelerating. If you've got one of these cars, you might think seriously of adding a longer filler pipe and relocating the neck to the quarter-panel.

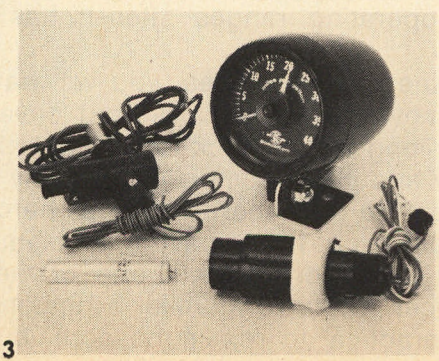
Smoothness is the key word in driving for better mileage. Avoid any sudden moves, whether they be sudden stops or sudden accelerations. Most drivers don't realize that every time they use the brakes, they're converting their fuel's energy into heat energy in the brakes. The more you use the brakes, the more your



1. No, we're not suggesting you do this, but we do want to emphasize that a careful right foot is one of the best tricks for better gas mileage.



2. Whether you install one in your dash permanently or just use it for tune-ups, a vacuum gauge is something every weekend mechanic should have. They can help in engine diagnosis—and driving by one teaches you to drive economically and consistently.



3. With a simple hookup to your fuel line and speedometer cable, this gas mileage meter by Spacekom reads mpg from 0-40 while you drive, to tell you just where your driving style is hurting you in the pocketbook.

4. It's been proven over and over again by hot rodders that relieving exhaust backpressure with a set of steel-tube headers is worth not only horsepower and torque, but mileage as well. Depending on how bad your stock system is, you can pick up from 2-6 mpg with headers and duals.

5. Fuel-pressure regulators aren't all that they may be claimed to be, but an adjustable one does seem to make sense. You can slow fuel pump pressure down on most cars to about 3 lbs. for improved mileage.

6. Along with headers, an efficient exhaust system should also have some large, straight pipes and free-flow mufflers like these Corvair turbo units which are street-quiet, too.

momentum is killed and the more gas you'll have to use to resume speed again. When driving in traffic, accelerate slowly and get into high gear as soon as possible without lugging the engine. Coast wherever it is legal and safe to do so, and when you see a red light ahead, don't buzz right up to it and slam on the brakes. If you can drive lazily up, so that the light changes before you get there, you'll have saved some energy by not destroying your forward momentum. When you *do* have to slow down or stop, use your brakes instead of downshifting a standard transmission. Downshifting makes the engine rev up and you're actually using more fuel to go slower.

INSTRUMENTATION

The energy crisis has been a real bonus to the aftermarket instrument people. Even Detroit is starting to offer vacuum gauges and such as options on new cars. Basic instruments that can prove helpful in driving for mileage are the good old tachometer and a vacuum gauge. The tach will tell you when you're lugging the engine or over-revving it, both undesirable conditions for economy. The tach and vacuum gauge are both valuable for engine tuning purposes, and if you're going after maximum economy you'll be doing some tuning for sure. Vacuum gauges have been referred to as "poor man's engine analyzers," because if you know just how to read one you can tell quite a bit about an engine through its vacuum readings under different conditions. Many vacuum gauges are marked with colored ranges that indicate "late timing," "bad plugs," etc., and these can be handy reference on all but the newest cars. New cars have such low vacuum readings to start with that the scales don't apply to them. Most gauges will also have power, cruise, and economy positions on the dial. Naturally, the idea is to drive so that the needle spends most of its time pointing to the economy setting.

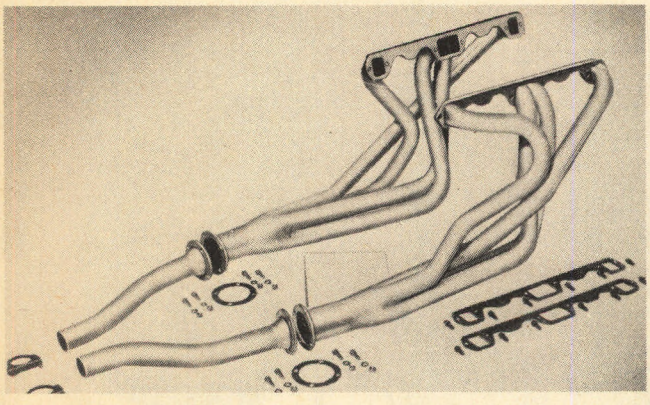
Another type of instrument being sold in droves now is the "mileage meter," a gauge to tell you how poor or how good your use of fuel is *while you drive*. The idea is that when you see the needle drop substantially every time you put your foot in it, you'll start driving in a more economical manner. Some good devices can be purchased for around $40 and installed without too much trouble. These mpg meters hook up to the speedometer to measure distance, and a sensor goes into the fuel line to read how much fuel is being consumed, with the gauge on the dash putting the info into mpg for you. Two of the devices introduced recently are by Aviatric Ltd., Box 7, Romsey S05 8XS, Hampshire, England, and Spacekom, Inc. of Goleta, Calif. The Spacekom unit is available through Sears automotive departments and through Hickey Enterprises, 1645 Callens Rd., Ventura, Calif. 93003. Spacekom's reads from 4 to 30 mpg and is said to be accurate within 3%.

EXHAUST SYSTEM

Of course, the sky's the limit in redesigning the internal combustion engine for greater efficiency and economy, but you're interested in what can be done at home, on a small budget and without an engineering department, right? Fortunately there *are* a number of things you can do at a reasonable cost. The first and most basic step would of course be to make certain the engine is in top stock tune to begin with. It's been estimated that if every car in America were in top tune, there would be no energy crisis at all, since a high percentage of the cars on the road today need at least some type of tuning or minor electrical parts that are robbing their owners of considerable mileage. Once you've tuned your engine for top economy in stock form, you have a baseline from which to work in comparing the effects of any modifications you make after that.

The biggest overall improvements on most cars can be made in the exhaust system. For years, dual exhaust systems have been touted as producing more power and acceleration, but people are finding now that they make just as much sense as a mileage modification. Freeing up the backpressure in your exhaust system is one of the few modifications you can make to a car that will benefit both performance *and* economy. Switching from a restrictive, stock single-exhaust system to a dual setup with two low-restriction mufflers should be worth one or two mpg—at a very reasonable cost. And when we say low-restriction mufflers, we don't mean the noisy little glasspacks sold everywhere for $9.95. Tests have shown that there are some excellent stock-design mufflers which have less backpressure (and consequently more power and economy) than the small glasspacks, even though the latter are straight-through design and the stock type are generally baffled. The best muffler we've ever seen is the one made for the old turbocharged model of the Corvair. Most of the major muffler companies have a replacement for this item which is selling like proverbial hotcakes today. With a 2½-in. inlet, a 2¼-in. core and a 2¼-in. outlet, it will breathe as well as any other muffler and yet is as quiet as most stock mufflers and much quieter than the usual glasspack. The Chrysler Imperial, International Harvester (part No. 376607-C1) and Chevrolet L-88 mufflers are also excellent, free-flowing and quiet mufflers.

Something many of you may have shied away from is a set of steel tubing exhaust *headers*. Up till now, it's been only the hot rod set which has benefited from backpressure-reducing headers, but now it should be clear to even the transportation-only crowd that these are one of the best mileage-improving steps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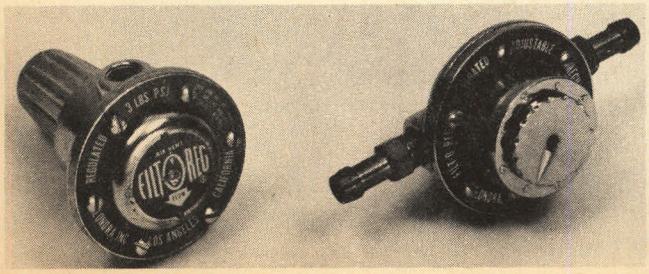
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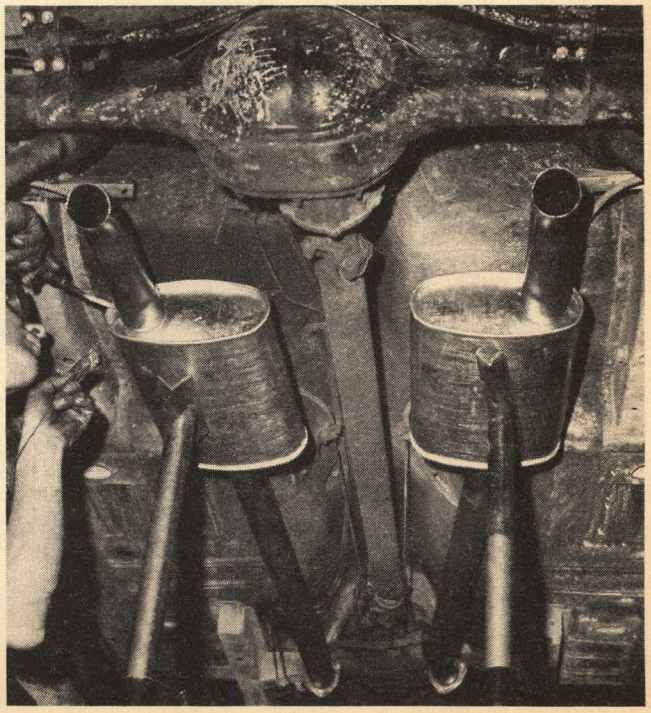
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you can take for the money invested. Most sets run $60 to $100 for a V-8 engine in a local speed shop or from a mail-order house, and on the average car they can pay for themselves in a year or so of driving. Our personal '66 Mustang with '71 302 engine (2-bbl.) went from 14.7 mpg with a stock single-exhaust system to an easy-on-the-pocketbook 20 mpg just by switching to headers and a pair of Corvair turbo mufflers! A gain like that would be hard to beat with any other single improvement at the same cost, and has the added benefit of more power and acceleration too. California Highway Patrol inspectors have remarked that the car is easily as quiet as many of the brand new cars they have inspected. Despite this rosy picture, advice on headers should not be without some cautions. In the East, where salts are used on winter roads, headers will rust out sooner than stock cast-iron manifolds, so replacement cost becomes a factor to weigh. Since the tubular headers do such a good job of scavenging the cylinders, they can create a *lean* condition; but on most cars a step up of one or two jet sizes in the carburetor cures this. Also, header bolts have a tendency to loosen up after awhile, and their tightness should be checked at normal underhood maintenance intervals.

OTHER ENGINE TIDBITS

We don't have the scope here to go into details of complicated internal modifications, so we'll concentrate on the simpler steps to better mileage. If you feel confident that you can change a camshaft at home, then there are a number of new designs on the aftermarket by Isky, Crane, Racer Brown, Crower and others, profiled specifically to give better gas mileage and low-end torque. There is some sacrifice in top-end speed, but these cams provide more drivability than even stock profiles. You may realize gains of one or two mpg with one of these cams, but you'll have to weigh the mileage advantages against the cost and trouble of switching cams.

Since it is common sense that a hotter engine will better vaporize the fuel-air mixture in the intake manifold, just switching to a hotter thermostat may give you a slight mileage edge. This would apply to older cars with thermostats of 160°-180°, since newer cars already have 190°-205° thermostats. Just make sure that your cooling system is in good condition and is able to stand the extra heat.

Smaller carburetors, or smaller jets in your existing carburetor, have always been a popular subject area for mileage discussions. The carburetor companies have recently come out with what they call "emissions-mileage" carburetors, which are basically just leaned-out. Switching from a 4-bbl. carb to a 2-bbl. has always been a popular mileage trick, but you should measure both carburetors to be sure you're really gaining something. Some 4-bbl.'s get *better* gas mileage than some 2-bbl.'s because of very small primary throttle bores in the 4-bbl., especially with the modern "spread-bore" designs. By just keeping your foot out of the secondary side of the carburetor and perhaps installing jets one size smaller, your 4-bbl. should do as well as most other carbs you could replace it with—without spending any money. After all, what good are all these mileage tips if they all cost you more than the savings you'd make? When rejetting your carburetor, make sure the engine is in tune, and keep going down in jet size until you get a noticeable lean-stumble condition while driving, then go back *up* one more jet size to eliminate the stumble. When driving at sustained freeway speeds, you might pay closer attention to the temp gauge now, since the leaner engine will run hotter.

We've warned you about the hucksters with their sensationally advertised ignition goodies for $4.95, but there really are some things to be done in the spark department besides keeping the engine tuned and timed. Some good things always come out of a crisis, and the gas crisis and tough smog legislation have spurred Detroit to develop ignition systems that keep pollutant levels low over a long period of time. The best of these devices are the new electronic ignitions.

1. The new "spread-bore" carb designs can sometimes provide better mileage than a 2-bbl. carb because the small primaries are economical, yet the seldom-used secondaries give you the performance when you need it.

2. Water injectors have been around in one form or another since WW II, but APO's unit admits vapors from a liquid chemical to idle-air port on your carburetor. The manufacturer claims better mileage, more power and lower emissions, some of which has been backed up by independent magazine tests for mileage gains.

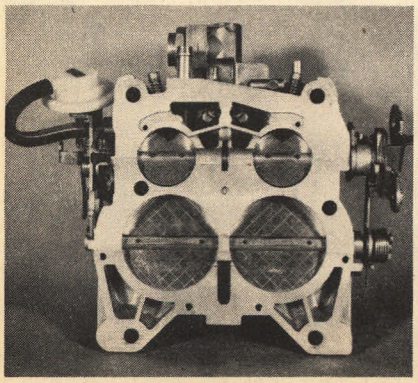
3. Aftermarket intake manifolds with the new single-plane designs like the Edelbrock Torker and Streetmaster, Weiand X-celerator, and Offenhauser Port-O-Sonic, coupled with emissions carbs like the Holley 6619, have shown significant improvements in late-model engine efficiency.

4. If your car doesn't already have a factory clutch fan, an investment in an aftermarket fiberglass or alloy fan can save up to one mpg by taking less horsepower to drive.

5. Two-barrel carbs can be adapted to most of the new mileage-emissions intake manifolds with a plate like this that locates the carb closer to the front than the rear. Some engines also show gains with a plenum divider plate like this under the carburetor.

6. Owners of Chrysler Corp. cars are lucky in the ignition department. The now-famous Chrysler electronic ignition is available from dealers in kit form for pre-'73 Mopars. At $68, it's a bargain in maintenance as well as emissions and mileage.

7. Even if you don't have a Mopar, you won't have to trade in your car to have the benefits of electronic ignition. Aftermarket units like this Hays Magna-Pulse breakerless are available in easily installed kits for Fords, GM, and even Mopars.



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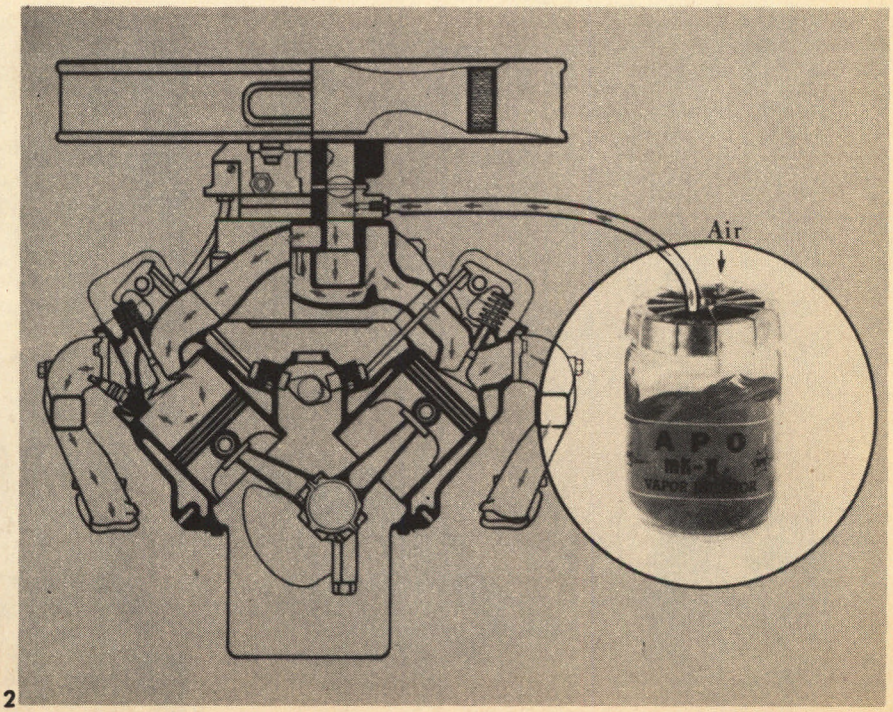

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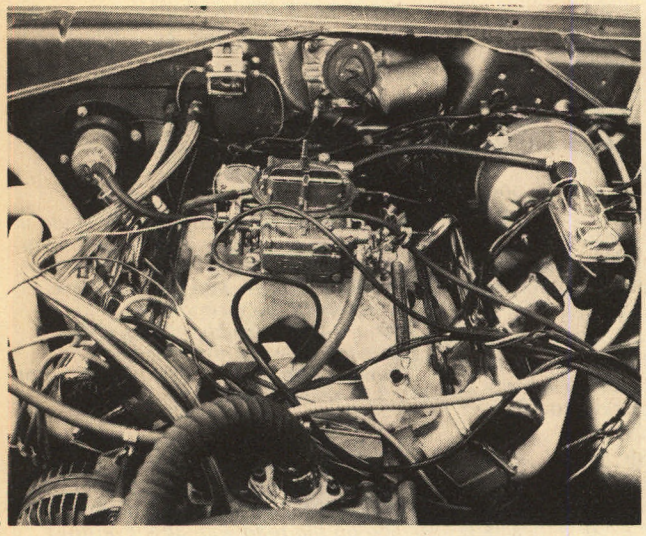
Chrysler was the first with a standard-equipment system and it has proven to be virtually maintenance-free. Some of the aftermarket companies are now making these systems too, and the best of them are *pointless* types like the Chrysler. By replacing the points with a magnetic pickup unit, the engine will stay in tune much longer (no point gaps to deteriorate), and the hotter spark keeps the plugs firing longer. Although there probably is no mileage gain over a perfectly tuned stock system, the pointless ignitions don't deteriorate between tune-ups; so over the long run, emissions are down and mileage should be improved slightly. A good unit like the Hays Magna-Pulse (17905 Sky Park Blvd., Unit H, Irvine, Calif. 92664) will also improve cold starting and acceleration. Hays has units for converting your stock GM or Ford distributor, as well as a unit for Chryslers. Chrysler owners are advised, though, that they can update their older Mopars with a kit from their dealer for about the same price. Accel also has a breakerless electronic ignition kit for all popular cars. Bad plug wires are hard to track down without special gear, and with today's hot underhood temperatures it's a good idea to replace your plug wires every 24,000 miles to be safe. When installing an electronic ignition, the manufacturers recommend installing new wires (preferably magnetic suppression wire with fiberglass core wrapped with monel wire) at the same time in order to ensure full efficiency.

Other mileage bolt-ons for the engine would have to include the new breed of lightweight cooling fans. Since it takes a certain amount of horsepower to drive a



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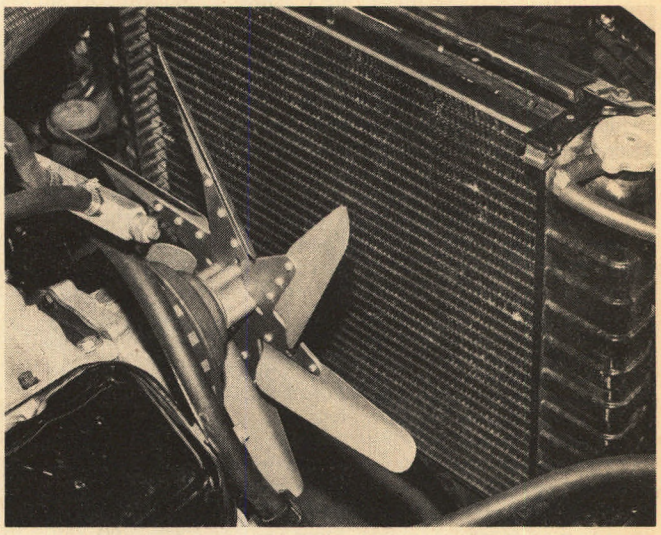

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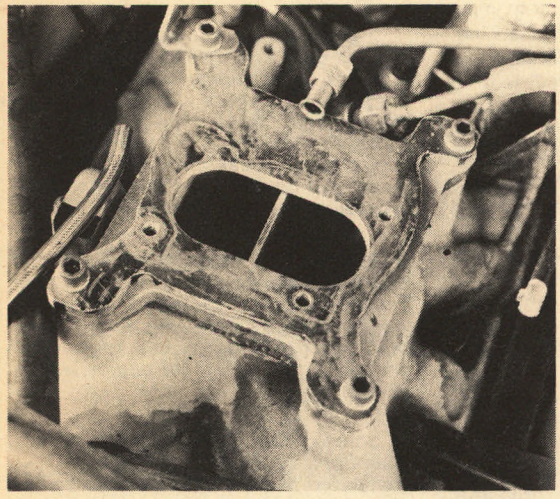

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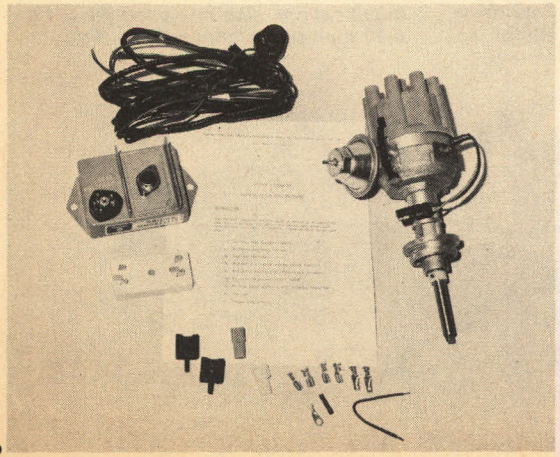

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Fuel Economy

stock steel fan, it makes sense that replacing it with a fiberglass or aluminum type would save some power. Many cars now have factory "clutch" fans that disengage at higher rpm to save power, and these work well also. The fiberglass and aluminum fans sold in speed shops and auto parts stores, in addition to being light, are supposed to flatten out at higher rpm to create less drag and soak up less horsepower. They also jazz up the engine compartment's looks, if that matters to you.

Fuel pressure regulators are now being touted as mileage tricks, but it's not that simple. Sure, if you cut down the fuel pressure to the carburetor you'll probably use less gas, but what about starving out when you're on the freeway? If for some reason your car has excessive fuel pump pressure, then by all means get an adjustable pressure regulator and cut down the flow. On most V-8 cars you can cut the fuel pressure down to about 3 lbs. and still have the car drivable.

While we're still on the subject of carburetion and fuel systems, this would be a good time to mention intake manifolds. The search for an intake manifold that can reduce exhaust emissions and still make power has spurred development of some new, single-plane aftermarket intake manifolds that work so well they may be copied by Detroit for '75 and '76 cars. The important thing to know about these manifolds, for you who are economy-minded, is that in addition to more drivability and lower emissions, they can also help the engine be a little more miserly with its petrol. An *efficient* engine should have a clean report card on emissions, power, *and* mileage—and that's just what these manifolds are designed to boost, efficiency. Edelbrock's new Streetmaster design is bringing a new breed of customer to speed shops—guys who never before would have bought a piece of speed equipment and now will buy anything to get decent gas mileage. Using a stock carburetor, cars whose manifolds are swapped for the Streetmaster consistently get better performance and improved economy by 10% or more. The other aftermarket manifold companies may also have something for you—and these parts are worth some investigation, if not from the mileage standpoint, at least from the "pre-smog motor" drivability they put back into a rough-running late-model car.

AN ECONOMICAL DRIVETRAIN

Everyone knows that a manual transmission provides for better gas mileage than an automatic transmission. Even though we have progressed out of the "slushbox" era to some really efficient 3-speed automatics, they still have some slippage, greater internal friction, and a hydraulic pump that takes extra power to drive. You probably knew there was a mpg or two difference when you bought your car, but you got the automatic anyway because you didn't know the energy crisis was coming, right? We're not going to suggest that you exchange your whole converter/trans package for the equivalent stick-shift pieces, because that's a lot of work—but some people are doing that today. Unless you're really attached to your car, it might be easier to trade yours in for a car that *has* standard-shift.

If you already have a standard transmission, good; but there is even more you can do. An overdrive unit is one of the best mileage goodies there is, and they're still available, both from the aftermarket and from any of those saviours of the backyard mechanic, the junkyards. Overdrive used to be a common factory option almost as long as cars have been built, but by the late '60's interest in the option had dwindled to the point where the manufacturers decided to drop it. Now that we are in an energy crisis, the importance of overdrive in fuel savings may bring it back again to the option list. Until then, you'll have to scour the wrecking yards to come up with a late-model overdrive for your make of car. If you already have a standard transmission, it won't be too difficult to make the conversion. You may have to change the driveshaft length to accommodate the new transmission and make the electrical or mechanical connections for the overdrive switch, but other than that it shouldn't be too difficult a job. One fellow we know of just did this with his 1972 Gremlin (304 V-8), and with no other changes to the car got 23 mpg on the highway!

If you have an automatic transmission, or can't find a rare overdrive unit in a wrecking yard, there is still a way out. The Hone Mfg. Co., 11748 E. Washington Blvd., Santa Fe Springs, Calif. 90670, makes 30% overdrive units to fit just about every kind of vehicle. Instead of attaching directly to the transmission, the Hone unit is installed in the driveline either just aft of the transmission or just ahead of the rear end, with its own crossmember. An added benefit of an overdrive unit is potentially increased performance around town. For instance, if the present rear end gear ratio in your vehicle is 3.23, then in top gear and with overdrive engaged this ratio would drop to the Bonneville Salt Flat level of 2.26! This means that you could easily change your rear end gears for a 4.10 ratio for more acceleration and performance around town, and still have great economy in overdrive, where the ratio would drop to 2.87.

It should be obvious to you now that rear end gearing has a lot to do with gas mileage. A lower-numerical ratio allows the engine to just loaf along when cruising, and although it will reduce the low-speed acceleration and performance, a ratio change like this can definitely im-

1. If you can't afford an overdrive, just changing your basic final drive ratio in the rear end can prove of substantial benefit in mileage.

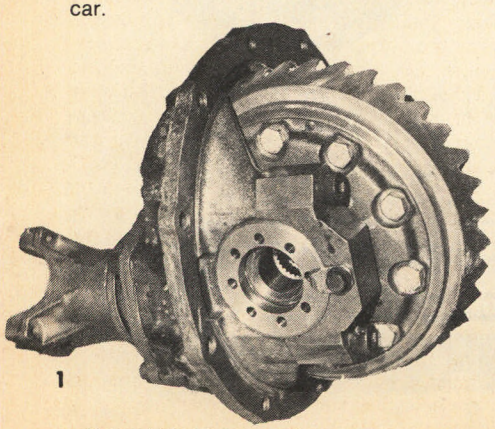
2. Few factory overdrives were made in the last 5 years, so chances of finding one may be slim, but whatever kind of vehicle you have, you can still have overdrive in the form of the Hone-O-Drive, which installs in the driveline between the rear end and transmission. Also a 30% unit, it'll drop a 3.23 gear to 2.26!

3. If you're lucky, like this 1972 Gremlin owner, you may find a late overdrive 3-speed for your car in a wrecking yard. With a 304 V-8, this setup produced 23 mpg on the road with 30% overdrive engaged.

4. If you have the know-how and the time to change a camshaft, some good gains in both mileage and low-end torque can be yours with one of the new RV cams like Isky's Mile-A-Mor or Crower's Gas-Stretcher. Like the single-plane intake manifolds, these cams can be worth the investment for drivability improvement alone.

5. Studying the economy results in this chart, you can see that just by juggling rear-end ratios, a car with a bigger engine can give the same performance with better mileage, even though with the same gear a smaller engine will always get better economy.

6. Some of the more commonly talked about mileage-improving steps are compared here with their actual gains on a typical big car, with surprising results. Almost all of the mileage modifications also improved the car's 0-60 mph performance times, too.



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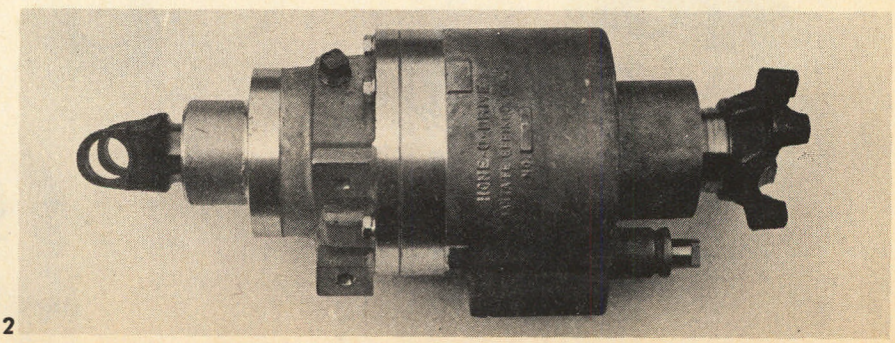

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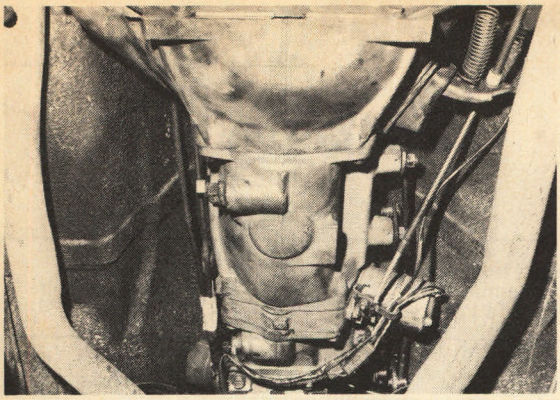

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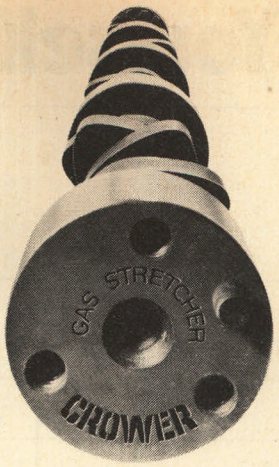

4

AXLE RATIO	3.23	2.93	2.56	2.29
390-CU.-IN. ENGINE				
Fuel Economy (mpg)				
Level Road—50 mph	17.4	18.2	19.7	21.1
Simulated City	13.7	14.0	14.6	15.0
Simulated Highway	15.0	15.9	16.5	17.7
Performance				
0-60 Time (secs.)	9.42	9.88	10.41	10.77
420-CU.-IN. ENGINE				
Fuel Economy (mpg)				
Level Road—50 mph	16.6	18.0	19.1	20.7
Simulated City	13.6	13.8	14.1	14.9
Simulated Highway	14.6	15.5	16.4	17.4
Performance				
0-60 Time (secs.)	9.02	9.05	9.35	9.99

5

ECONOMY AND PERFORMANCE	50 mph level road	Simulated city	Simulated highway	0-60 time
Base Line Run 420-cu.-in. engine 2.29 axle ratio	20.7	14.9	17.4	9.99
Same as above except: with radial-ply tires	21.1	14.7	17.5	—
Same as above except: with 10.5 to 1 compression ratio	21.4	15.2	17.6	9.22
Same as above except: with free flowing dual exhaust system	21.7	15.2	18.1	8.68
Same as above except: with fan clutch	22.2	15.7	18.4	8.36
Same as above except: with 4-bbl. carburetor	22.6	15.7	18.5	7.62

6

prove fuel mileage. Even a big car with a big engine can give better mileage than an intermediate car when equipped with the right ratio, and may still have better performance. Check the chart with this story for some suprising facts about big-car mileage. If you can't afford the overdrive route, then maybe what you should do is just change your rear end ratio to a lower-numerical one. It's not a job that is within the capabilities of every weekend mechanic, but most dealerships can do the job for you.

CHASSIS TUNING FOR ECONOMY

Tuning a car for economy can encompass many facets of a vehicle besides just the engine—there's some gasoline to be saved in the chassis, too. Your brakes, tires and front end alignment all have to do with the fuel that is consumed to power the car down the road. You can't "detune" your brakes the way you can your engine by switching to a smaller carburetor, but what you can do is eliminate some of the possible drag there that may be eating into your highway mileage. If you have front disc brakes, there's not much you can do with them, for they have a certain amount of drag inherent in their design and there are no adjustments for this, but you *can* do something with your drum brakes, which is why drum brakes are probably more economical in terms of mileage. Just switching to heavy-duty shoe-return springs and eliminating the self-adjusting mechanisms (there are kits for this job available in most auto parts stores) will ensure that there is no power-robbing rolling resistance in the braking system. If you're planning a brake overhaul anyway, then go one step further and make these changes too.

Since your tires are the final contact between your car and the road, they are very much a part of a car's fuel economy picture. How they're inflated, aligned, and even what type of tire they are has a lot to do with the vehicle's rolling resistance. There has been considerable talk of late (spurred by heavy advertising programs from the tire companies) about how radial-ply tires will save you gasoline. It's true. Because of their more flexible sidewall construction, radial-ply tires offer less rolling resistance because there is less energy wasted on heat and friction between the plies than on a conventional or bias-belted tire. There should be at least a half-mpg to be saved on steady highway travel with radials, but less around town because the rolling resistance is less of a factor in stop-and-go driving. Because radials last longer than conventional tires (although they naturally cost more, too) they may also save you money in the long run of car ownership by reducing costs of tire rotating, mounting and balancing. It's false economy to run inexpensive tires if you do a lot of driving, because you'll be spending money for these tire services more often.

It goes without saying that your tires, of whatever construction, should be cared for regularly. Keeping the front end aligned properly and the tires at optimum inflation will not only assure you of the best possible fuel mileage but will also save money on the life of the tires themselves.

BUYING A CAR

We've shown you some of the things you can do with a car to improve fuel economy, but if you're not the home-mechanic type (then why are you reading this book?), then you can at least look for some of these econo-features in the next car you buy. Studying our chart will show you that small cars aren't the only ones capable of 20 mpg, so don't sell the intermediate cars short if you have a family that can use one. Some of the features or options to look for in a car would be radial tires, standard transmission, 5-speed or overdrive if available, de-clutching fan, dual exhausts, numerically low axle ratio, and a small engine. Don't purchase such options as air conditioning (eats at least one mpg or more), or power steering unless you really *need* them. Not all manufacturers offer them, but cruise control and electronic fuel injection are two options that are worth looking into for their savings in petrol.

Not all of the tips we've included in this story will give you the same results our tests have given, but the trends will be the same. A free-flowing exhaust system, for instance, will save in varying amounts depending upon how restrictive the car's stock system was. If this chapter doesn't give you information you can apply to your present car, at least you'll know what to look for when shopping for a new or used one. Not knowing where the price or availability of gasoline is going in the future, more and more, mileage-saving steps will be worth the initial investment cost compared to the long-run savings in fuel costs. And keeping the present environmental state in mind, what we do to save fuel ensures there'll be some around tomorrow.

Log of Do-It-Yourself Savings

Date	Job	Quotation from Dealer or Mechanic (Parts and Labor)	Cost of Parts	Do-It-Yourself Savings